SOIL SURVEY

Sulphur Spring Valley Area Arizona

Series 1940, No. 14

Issued November 1954

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Conservation Service

In cooperation with the

UNIVERSITY OF ARIZONA AGRICULTURAL EXPERIMENT STATION

How to Use THE SOIL SURVEY REPORT

FARMERS who have worked with their soils for a long time know about the soil differences on their farms, perhaps also on the farms of their immediate neighbors. What they do not know, unless soil surveys have been made, is how nearly their soils are like those on experiment stations or on other farms, either in their State or other States, where farmers have gained experience with new or different farming practices or farm enterprises. They do not know whether higher yields obtained by farmers in other parts of the area and State are from soils like theirs or from soils so different that they could not hope to get yields as high, even if they followed the same practices. One way for farmers to do away with some of the risk and uncertainty involved in trying new production methods and new varieties of plants is to learn what kinds of soils they have so that they can compare them with the soils on which new developments have proved successful.

SOILS OF A PARTICULAR FARM

The soil map accompanies this report. To find what soils are on any farm or other land, it is necessary first to locate this land on the map. This is easily done by finding the township in which the farm is located and by using landmarks such as roads, streams, villages, dwellings, and other features to locate the boundaries.

Each kind of soil mapped within the farm or tract is marked on the map with a symbol. For example, all the areas marked Hc are Hooker sandy loam. The color in which the soil area is shown on the map will be the same as the color indicated on the legend for the particular type of soil. If you want information on the Hooker soil, turn to the section in this publication on Soil Series, Types, and Phases and find Hooker sandy loam. Under this heading, you will find a statement of what the characteristics of this soil are, what it is mainly used for, and some of the uses to which it is suited.

If you wish to know how well Hooker sandy loam is suited to irrigation, turn to the section on Classification of the Soils for Irrigation.

SOILS OF THE AREA AS A WHOLE

A general idea of the soils of the area is given in the section on Soils. After reading this section, study the soil map and notice how the different kinds of soils tend to be arranged in different parts of the county. These patterns are likely to be associated with well-recognized differences in types of farming, land use, and land-use problems.

A newcomer to the county, especially if he considers purchasing a farm, will want to know about the climate; the principal farm products and how they are marketed; availability of roads, railroads, and electric services; water supplies; and population characteristics. Information about all these will be found in the sections on General Nature of the Area and on Agriculture.

Those interested in how the soils of the area were formed and how they are related to the great soil groups of the world should read the section on Morphology and Genesis of Soils.

This publication on the soil survey of the Sulphur Spring Valley area, Arizona, is a cooperative contribution from the—

SOIL CONSERVATION SERVICE

and the

UNIVERSITY OF ARIZONA AGRICULTURAL EXPERIMENT STATION

Series 1940, No. 14 Issued November 1954

SOIL SURVEY OF THE SULPHUR SPRING VALLEY AREA, ARIZONA[1]

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[1] The field work for this survey was done while the Division of Soil Survey was a part of the Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration. Soil Survey was transferred to the Soil Conservation Service Nov. 15, 1952.

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THE Whitewater Division, the Kansas District, and the Willcox Division, make up the surveyed area in Sulphur Spring Valley. They lie in the central part of the valley where ground water generally occurs within 120 feet of the surface. The valley is in the heart of an extensive grassland area where much of the natural vegetation furnishes fair to good forage. Cattle raising is the principal agricultural enterprise. Chickens, turkeys, and sheep are other important livestock. Alfalfa, barley, wheat, grain sorghums, and corn are grown for supplemental feed. Since electric power has become available for pumping, the irrigated acreage has increased. Cotton, beans, chili peppers, and other vegetables are leading cash crops; cotton, particularly, has become important in recent years. To provide a basis for the best uses of the land, this cooperative soil survey was made by the United States Department of Agriculture and the University of Arizona Agricultural Experiment Station. Field work was completed in 1940, and, unless otherwise specifically mentioned, all statements in this report refer to conditions in the Sulphur Spring Valley area at that time.

GENERAL NATURE OF THE AREA

LOCATION AND EXTENT

The Sulphur Spring Valley area (fig. 1) covers three separate districts in the wide valley plain of the Sulphur Spring Valley, which extends in a north-south direction through the central part of Cochise County, Ariz. The total land area covered by the survey is about 259 square miles, or 165,760 acres. Willcox, in the northern part of the area is 65 miles east of Tucson and 65 miles north of the Mexican

border (air distances). Bisbee, the county seat, is about 9 miles west of the southern limit of the survey.

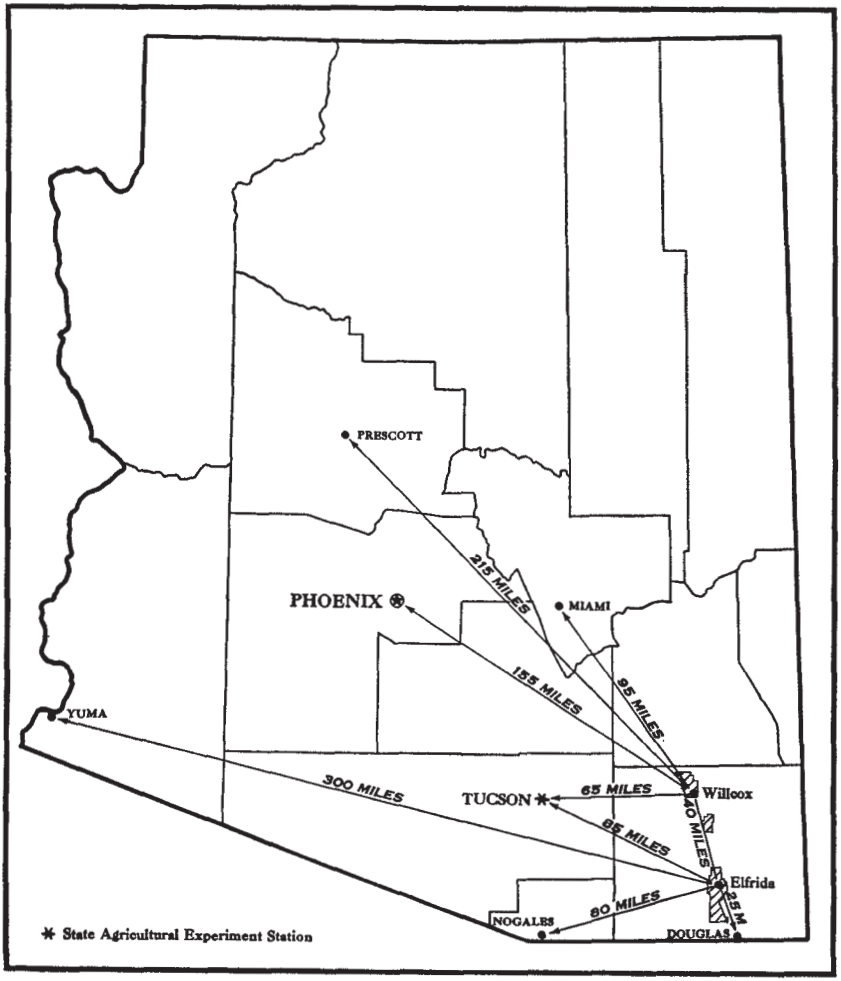

FIGURE 1.—Location of the Sulphur Spring Valley area in Arizona.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

Sulphur Spring Valley lies in the Mexican Highland section of the Basin and Range province, south of the high Colorado Plateaus. This valley averages about 20 miles in width and is bordered on the east and west by chains of mountain ranges having a north-northwestward trend. The area surveyed is in the central part of the valley, where ground water generally occurs within 120 feet of the surface.

About 38 miles north of the Mexican border, a chain of low volcanic ridges or hills divides the watershed draining south into the Whitewater Draw from that draining north into the Willcox Playa. The

area surveyed in the Whitewater Division, or Whitewater drainage basin, includes 153 square miles. Adjacent to the playa, which is about 13 miles north of the divide, is an area of 33 square miles locally known as the Kansas District. The remaining 72 square miles of the area surveyed lie northwest of Willcox and are referred to as the Willcox Division. This area extends northward from Willcox to within 2 miles of the Graham County line.

The lowest elevation [2] (slightly less than 4,000 feet above sea level) occurs along Whitewater Draw at the southern margin of the area. None of the area surveyed in this watershed is more than a few hundred feet above this elevation. Elfrida, about midway between the highest and lowest points, has an elevation of 4,143 feet. Whitewater Draw descends into the area from the northeast on gently inclined alluvial-fan slopes without any definite channel. In the southern part of the area is about 10 miles of incised channel. This channel is very shallow west of McNeal but becomes 10 to 20 feet deep and 30 to 100 feet wide near and beyond the southern border of the area. In the lower part of the area are many deep short gullies tributary to the main channel, but most of the intermittent tributaries give way to sheet wash that spreads over gently inclined fan slopes. Most of the soils adjacent to the Whitewater Draw are highly impregnated with salts.

The Kansas District occurs at an average elevation of 4,200 feet. It is a gently westward-sloping plain that consists of the lower stretches of alluvial fans. Streams have no definite channels, and waters spread in sheets over grassy flats where the alluvial fans merge with the Willcox playa. Some of the soils are strongly impregnated with salts. Successive layers of caliche occur at shallow depths. A beach line of an ancient lake lies along this area on the west. The present ground water is 20 to 120 feet below the surface.

According to geologists [3] a lake once covered the present site of Willcox and probably extended several miles west and north. The shore line is obliterated by old delta deposits from former meandering streams of the present ill-defined Hookers Draw. A large part of the Willcox Division occurs in this delta plain, which is gently inclined northward. Its sides are significantly modified by the lower reaches of gently rising alluvial fans that extend from the parallel mountain chains on either side. Willcox, on the old lake flat, is 4,156 feet above sea level. Neither the delta plain nor the alluvial fans attain an elevation greater than 4,300 feet within the area surveyed.

This area lacks stream channels, and drainage waters from Hookers Draw and the alluvial fans cover extensive flat areas and depressions after heavy rains. Though these waters remain only a short time, alluvial materials are frequently deposited. Extensive and successive underground caliche strata occur.

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[2] Elevations from U. S. Geological Survey topographic maps.

[3] MEINZER, O. E. and KELTON, F. C. GEOLOGY AND WATER RESOURCES OF SULPHUR SPRING VALLEY, ARIZ. (With a section on agriculture by R. H. Forbes.) U. S. Geol. Survey Water Supply Paper 320, 231 pp., illus. 1913.

CLIMATE

Sulphur Spring Valley has the characteristic bright weather and intense sunlight of the arid Southwest. Winters are mild, and summers lack the intense heat of the lower altitudes in Arizona. The precipitation and humidity are low and the rate of evaporation high.

On all soils in this area plant growth is limited principally by lack of moisture. The rainfall is insufficient to support anything but grass and semidesert vegetation, and few plants of economic importance can be grown without additional water supplied by irrigation. Temperature and humidity are unfavorable for some species and varieties of plants, and frosts prevent the growth of tender vegetation during winter. Many crops may be grown successfully, however, if planting is done so as to take advantage of the more favorable climatic conditions or if climatically adapted varieties are selected. On soils that have favorable structure and good inherent fertility, the growth of crops is limited mainly by climate.

The average annual temperatures of 58.5° F. for Willcox and 62.6 for Douglas (just south of the surveyed area) indicate the relative mildness of the climate. The daily range in temperature is high, and nights are generally cool even in hot weather. The highest temperature recorded at Willcox is 110°, and at Douglas 111°; the lowest is 2° and −7°, respectively. Though very little snow falls, there are several months during winter when cold weather retards farm work. Winter grains may suffer from alternate freezing and thawing during this period. Livestock graze throughout the year.

The average frost-free season at Willcox is 185 days (April 24 to October 27) and at Douglas, 211 days (April 6 to November 4). Intermediate points in the valley probably vary between these two extremes. Late spring and early fall frosts sometimes endanger fruits, tender vegetables, and cotton, especially in the Willcox Division. The latest spring frost recorded at Willcox was on May 31, and at Douglas, May 11. The earliest frost in fall occurred on October 2 at Willcox, and on October 5 at Douglas.

The average annual precipitation at Willcox is 11.84 inches, and at Douglas, 12.71 inches. The quantity of rainfall varies greatly from year to year. The highest recorded rainfall at Willcox is 23.52 inches, and the lowest, 5.57. Records at Douglas indicate similar variations. Most of the precipitation comes as torrential rains during July, August, and September, and the rest chiefly as gentle rains from December to March. Snow in any appreciable quantity is not common.

The prevailing winds are from the southwest and are somewhat high during spring but not generally destructive to property. Wind accentuates the rate of evaporation which, as recorded at Willcox, averages 86.87 inches annually.

Table 1 gives the normal monthly, seasonal, and annual temperature and precipitation at Willcox and Douglas as reported by the United States Weather Bureau.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Willcox and Douglas, Cochise County, Ariz.*

Month	Temperature [1]			Precipitation [2]			
	Average	Absolute maximum	Absolute minimum	Average	Total for the driest year	Total for the wettest year	Average snowfall
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
WILLCOX, ELEVATION, 4,200 FEET							
December	42.2	81	9	1.01	0.46	1.06	1.6
January	40.6	78	2	.71	.11	2.56	1.4
February	44.8	84	6	.92	.00	3.91	1.6
Winter	42.5	84	2	2.64	.57	7.53	4.6
March	49.3	93	9	.59	1.64	5.00	1.5
April	56.5	94	19	.23	.53	1.41	0
May	64.0	104	25	.22	.06	.00	0
Spring	56.6	104	9	1.04	2.23	6.41	1.5
June	72.7	110	34	.40	.04	.77	0
July	77.6	110	42	2.21	.66	1.34	0
August	75.7	108	46	2.82	1.98	1.89	0
Summer	75.3	110	34	5.43	2.68	4.00	0
September	70.3	105	33	1.42	.07	1.58	0
October	60.0	95	18	.55	.02	.37	0
November	48.4	91	8	.76	.00	3.63	.1
Fall	59.6	105	8	2.73	.09	5.58	.1
Year	58.5	110	2	11.84	[3] 5.57	[4] 23.52	6.2
DOUGLAS, ELEVATION, 4,010 FEET							
December	46.0	81	6	0.89	0.43	5.70	0.9
January	45.5	82	−7	.63	.24	.48	1.5
February	49.5	89	12	.74	.04	.65	.7
Winter	47.0	89	−7	2.26	.71	6.83	3.1
March	54.5	94	17	.52	.40	.41	.4
April	60.8	97	26	.28	[5]	.00	[5]
May	68.3	106	30	.21	.00	.80	0
Spring	61.2	106	17	1.01	.40	1.21	.4
June	77.4	110	42	.52	.09	.25	0
July	80.0	111	41	3.12	.70	5.20	0
August	78.1	107	49	2.97	.78	6.19	0
Summer	78.5	111	41	6.61	1.57	11.64	0

See footnotes at end of table.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Willcox and Douglas, Cochise County, Ariz.*—Con.

DOUGLAS, ELEVATION, 4,010 FEET—Continued

Month	Temperature [1]			Precipitation [2]			
	Average	Absolute maximum	Absolute minimum	Average	Total for the driest year	Total for the wettest year	Average snowfall
	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*	*Inches*
September	74. 2	101	29	1. 31	0. 98	0. 21	0
October	64. 1	95	23	. 79	. 27	2. 78	0
November	52. 9	89	14	. 73	. 83	1. 08	[5]
Fall	63. 7	101	14	2. 83	2. 08	4. 07	0
Year	62. 6	111	−7	12. 71	[6] 4. 76	[7] 23. 75	3. 5

[1] Average temperature for Willcox is based on a 69-year record, 1883 to 1951, and for Douglas, a 45-year record, 1903 to 1947; highest and lowest temperatures for Willcox are based on a 30-year record, 1901 to 1930, and for Douglas, a 28-year record, 1903 to 1930.

[2] Average precipitation for Willcox is based on a 70-year record, 1882 to 1951, and for Douglas, a 9-year record, 1943 to 1951; wettest and driest for Willcox are based on a 69-year record, 1883 to 1951, and for Douglas, a 62-year record, 1890 to 1951; snowfall for Willcox is based on a 27-year record, 1904 to 1930; record years for Douglas was not reported.

[3] In 1924. [4] In 1905. [5] Trace. [6] In 1936. [7] In 1914.

WATER SUPPLY

Ground water of good quality for both domestic and irrigation purposes can be obtained at 20 to 120 feet throughout most of the area. Artesian wells are located on several farms in the Kansas District. They are 400 to 700 feet deep and usually flow about 50 gallons a minute. Wells for pump irrigation are 50 to 250 feet deep and are usually larger in diameter than the deeper artesian wells. An average flow of 250 to 300 gallons a minute is obtained, but a few larger wells supply 1,000 gallons a minute.

VEGETATION [4]

The native vegetation still persists over much of the area, although overgrazing has caused some changes. In general, the higher lying and better drained soils support mesquite (*Prosopis juliflora* and *P. glandulosa*) and various perennial and annual grasses; and the lower, more poorly drained soils support occasional mesquite bushes, Mexican saltgrass (*Eragrostis obtusiflora*), saltgrass (*Distichlis stricta*), and alkali sacaton (*Sporobolus airoides*).

The important perennial grasses on the higher lying soils are largely tobosa (*Hilaria mutica*), sacaton (*Sporobolus wrightii*), burrograss

[4] Common plant names used in this report are those generally used by inhabitants of the area surveyed.

(*Scleropogon brevifolius*), Rothrock grama (*Bouteloua rothrockii*), and occasionally blue grama (*B. gracilis*), three-awn (*Aristida* sp.), and feathergrass (*Andropogon saccharoides*).

On the more sandy droughty ridges are found yucca (*Yucca elata*), Mormon-tea (*Ephedra* sp.), fluffgrass (*Tridens pulchellus*), six-weeks grama (*Bouteloua barbata*), and needle grama (*B. aristidoides*). On some of the more calcareous alluvial-fan soils near Elfrida, almost solid stands of blackbrush (*Flourensia cernua*) interrupt the more continuous mesquite growth. In mesquite thickets on low areas that are flooded during rainy seasons there is a scattering of acacia, hairy squawbush (*Rhus trilobata*), and lotebush (*Condalia* sp.). Many grazing areas and abandoned farms are being rapidly invaded by broomweed or snakeweed (*Gutierrezia sarothrae*) and to some extent by burroweed (*Aplopappus tenuisectus*).

Annual herbs and grasses that grow beneath the mesquite during the rainy periods of winter and summer are usually short lived. Many are important grazing plants, as alfileria (*Erodium cicutarium*), Indian-wheat (*Plantago fastigiata*), and a number of annual gramas (*Bouteloua* sp).

Transitional from the mesquite areas and extending to the saltgrass flats are extensive areas of scattered chamiza, or fourwing saltbush (*Atriplex canescens*), and saltbush (*A. griffithsii*). Seepweed (*Suaeda* sp.) is becoming established on abandoned salty lands and adjoining areas that are not sod-bound. Alkali sacaton is prominent in this transitional belt as well as in saline areas.

ORGANIZATION AND POPULATION

Settlement of Sulphur Spring Valley was almost impossible from the time of the Gadsden Purchase (1853) until 1872 because of warring Indian tribes. After the Indians were subdued, however, permanent cattle ranches and settlements sprang up throughout the valley.

In 1880, the main line of the Southern Pacific Railroad was built across the northern part of the valley, and Willcox became a supply station for the surrounding territory. About this same time, rich silver ore deposits were discovered in the nearby mountains, notably close to Tombstone and Bisbee. These industries attracted a large population, and scattered mining and smelting centers created demands for agricultural products. It was not until after 1905, however, that there was any considerable movement to the agricultural lands of the valley. The greatest influx came in 1910 and the period following.

Willcox (population 1,266 in 1950) is the largest town in the area surveyed. Bisbee, the county seat, had 3,801 inhabitants in 1950 but is located about 9 miles south of the area. These are the two main shipping and trading centers for the valley. The rural population is centered in the small towns of Elfrida and McNeal and near the Double Adobe and Stewart Schools. Many inhabitants are from adjoining and South Central States.

RAILROADS AND ROADS

Main and branch lines of the Southern Pacific Railroad serve Douglas (outside the area) and Willcox. Paved highways in the

Whitewater Division provide excellent contact with Douglas, Bisbee, and other markets. Connecting roads often are paved, graveled, or graded, but some parts are accessible only by trails. A gravel-surfaced road runs north through the Kansas District to Willcox. Willcox is situated on a paved highway (U. S. 666), and the adjacent territory is served by paved, graveled, or graded roads.

SCHOOLS, CHURCHES, AND FARM IMPROVEMENTS

Graded schools are maintained throughout the area. High schools are at Willcox and at Pearce, and some students in the Whitewater Division attend the high school at Douglas. School bus transportation is available in outlying districts. Churches and assembly halls are in the towns and most community centers.

A cooperative rural electric system supplies electric power to farms where there is sufficient demand. Telephone service is available in the towns and most outlying communities.

The largest investments for farm improvements are for dwellings, fences, and wells and pumping equipment. Owing to the mild winters, little or no protection is necessary for livestock. Fences are well built and in good repair.

AGRICULTURE

EARLY AGRICULTURE

Although little farming was carried on by the Indians when the first white settlers came to the valley, evidence of a prehistoric agriculture existed in the form of abandoned irrigation ditches and corn-grinding metates (stones with a concave upper surface). The early settlers took little interest in agricultural development other than that supplementary to the cattle industry. The influx of people to mining and smelting centers gave the first impetus to a more diversified agriculture. By 1910, or soon thereafter, much of the area was homesteaded and there was both dry and irrigation farming.

During this early period, grain sorghums, beans, and corn were the favored crops because they thrived and matured rapidly during the hot summer rainy period when moisture was most abundant. Many practices of the Indians, including that of diverting floodwaters to the lands, were closely followed. Efficient dry-farming methods supplemented by use of floodwaters, applied directly or stored, or by use of water from underground pumping in the shallow water belts gave fair returns with minimum expense.

This kind of farming was replaced gradually by more reliable practices in which motor-driven pumps were used to furnish a stable irrigation supply from the shallow underground water. In addition to those crops formerly raised, such crops as alfalfa, small grains, and fruits that required more moisture and a longer growing season were introduced. From 1918 until the late 1920's there was a rapid expansion in the irrigated acreage, though the proportion was small compared to the open range used for grazing. This period was followed by a marked decrease in cultivated acreage, but by 1940 the acreage was increasing rapidly. A cooperative rural electric system that supplies reasonably priced and dependable power has created new interest in shallow water belts or areas where pumping is economically feasible.

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CROPS

Cultivated crops are grown on a proportionately small acreage and their production is supplementary to raising of cattle, sheep, poultry, and other livestock. No census figures are available that are strictly applicable to the valley. Field records made during progress of the survey indicate that in 1940 about 4,200 acres was irrigated, 756 acres was dry-farmed (usually with supplementary floodwaters), and 750 acres was cleared but not under irrigation. Approximately 21,000 acres was irrigated in 1948.

Table 2 gives the principal crops and number of bearing fruit trees and grapevines in Cochise County in stated years. As the surveyed area is in this county, the table indicates some of its crops.

The most important crops are cotton, alfalfa, grain sorghums, and chili peppers. Corn, dry beans, barley, wheat, potatoes, and sweetpotatoes occupy smaller acreages. Some vegetables are grown on truck farms near the Double Adobe School and in farm gardens throughout the area. A few small orchards produce mainly apples and peaches. Plums and apricots are used largely for yard plantings, and grapes are grown successfully. Blackberries, boysenberries, and strawberries are grown in home gardens.

The acreage in cotton has increased tremendously since 1947. Several cotton gins are located in the area. Acala, a short staple variety, was preferred but has been replaced by improved strains. Yields have been reduced by frost in some places.

TABLE 2.—*Acreage of principal crops and number of bearing fruit trees and grapevines in Cochise County, Ariz., in stated years*

Crop	1929	1939	1949
	Acres	*Acres*	*Acres*
Cotton	(1)	(1)	11,655
Corn harvested for grain	590	467	438
Small grains threshed or combined:			
Wheat	223	304	219
Oats	(1)	23	206
Barley	29	299	390
Grain sorghums for all purposes	750	2,077	2,604
Dry beans harvested for beans	1,151	6,961	449
Irish potatoes for sale or home use	61	24	[2] 4
Chili peppers for sale	8	20	934
All other vegetables for sale	815	298	312
All hay	4,809	4,466	3,918
Alfalfa	1,179	1,318	2,412
Small grains cut green	124	341	320
Wild, salt, or prairie grasses	2,924	1,782	798
Other tame hay	582	1,025	388
	Number	*Number*	*Number*
Apple trees	7,243	8,161	4,631
Peach do	8,432	7,244	5,843
Pear do	900	732	591
Cherry do	119	78	(1)
Plum and prune do	1,332	908	504
Fig do	183	124	(1)
Apricot do	380	408	445
Walnut do	115	305	(1)
Grapevines	10,692	3,128	1,532

[1] Not reported.

[2] Does not include acreage for farms with less than 10 bags harvested.

Alfalfa is valuable in rotation with other crops because it supplies organic matter and nitrogen and thus builds up and maintains fertility. The Chilean variety is grown almost exclusively. Five cuttings are usually obtained annually. It is one of the best hay crops in both yield and quality and can often be raised satisfactorily without the use of fertilizers and amendments. As a supplementary feed, it is as important as hegari (grain sorghum) in this area and exceeds it in acreage since electric power has become available for comparatively cheap and efficient pumping. Demand for hay, especially in dry years, exceeds supply, and alfalfa is frequently shipped in from outside.

Of the grain sorghums, hegari is raised most widely. Before selling their calves and short yearlings, many farmers profitably supplement range and farm grazing with sorghum grain and other feeds.

Beans are an important cash crop because they grow and mature quickly during the summer rainy season. The Pinto variety of dry bean is preferred and is grown almost exclusively.

Chili is an important cash crop in the Whitewater Division, and two dehydrating plants have been established. After being dried, the crop is shipped to other processing plants outside the area.

Barley and wheat are the most important small grains, but the total acreage is small. Common Six-Row is the best adapted barley and the most popular. Barley, like hegari, has a relatively high tolerance for soluble salts and is often used in reclaiming salty soils. It is also popular as a nurse crop for alfalfa seedings. Wheat is raised almost entirely for grain, and Early Baart is the principal variety.

Corn is raised for grain, fodder, and silage. It has a higher water requirement than hegari, however, and is not so desirable. The Mexican June variety is usually grown.

Lettuce, cantaloups, potatoes, sweetpotatoes, carrots, red beets, and radishes are the principal truck crops. Onions, summer squash, sweet corn, spinach, cauliflower, melons, tomatoes, and peas are less important. The leafhopper endangers some of the succulent plants. Most vegetables are sold at local markets.

PASTURES

Most of the valley grassland and browse, as well as the adjacent mountain country, is used for range. Owing to the wide spread of natural range, little attention is given to improved permanent pasture. Cattle and other livestock are often permitted to graze fields of alfalfa or grains before or after the harvesting season. Sweetclover has been used some for pasture. The perennial grama grasses provide the best forage; tobosa is rated low but provides good feed when green. Sacaton provides fair to good all-year pasture. Of the browse plants, mesquite and the saltbushes are predominant and are considered good.

AGRICULTURAL PRACTICES

Tillage is almost entirely by tractors, and practices are improving as new attachments become available. Fields can be plowed at almost any season.

Grain sorghums are planted from the last week in May through June. The middle of June is considered best. The time of irrigation

and the quantity of water applied vary with the rainy season. Crops often mature on 1½ acre-feet of water in wet seasons, but the average is 2 acre-feet.

Alfalfa is not yet used so commonly as it should be in crop rotations, as it is important in building up and maintaining the organic matter and nitrogen in the soils. Fields of alfalfa often remain until yields decline. Fall seeding of alfalfa, preferably in October, usually assures a good stand in spring. At present, however, most alfalfa is seeded in February and March. About half of the seedings are made with barley as a nurse crop. Two irrigations for each cutting of alfalfa are usually required, but the number and quantity vary with the soil. The annual application is usually 4½ to 5 acre-feet.

Beans are usually planted in late May or during June. The annual application of water required varies from 1½ to 2½ acre-feet, depending on the soil and seasonal rainfall.

Barley is seeded in both fall and spring, but wheat usually in fall only. When barley is seeded as a nurse crop with alfalfa, there is considerable latitude in time of planting. November is considered the best time to plant wheat. Wheat and barley require 2 to 2½ acre-feet of water a season. Corn is planted about the same time as grain sorghums, and its water requirement is about ½ acre-foot greater.

Commercial fertilizers are used to a limited extent. Alfalfa planted in soils low in phosphate should respond to annual applications of 50 to 60 pounds of available phosphorus per acre. Wheat, barley, oats, sorghum, and corn will respond most often to nitrogen. From 50 to 100 pounds of nitrogen per acre should be used. No fertilizer should be needed on land just out of alfalfa. Cotton will respond most often to nitrogen. As a general rule, 50 pounds of nitrogen per acre should be adequate.

Soil amendments have not been widely used. A few applications of gypsum have been made for the reclamation of alkali soils.

LIVESTOCK AND LIVESTOCK PRODUCTS

Livestock and livestock products provide the larger part of cash income in the valley. On the average more than 60,000 beef cattle are sold annually. Most are Herefords, and their quality is steadily improving owing to the use of purebred bulls. Willcox is one of the largest shipping points for cattle in the United States. Most cattle are shipped to feed lots in the Salt River Valley, in California, or in the Middle West. A few farmers raise feed enough to fatten their calves in the feed lot, but most calves are sold directly from the range.

Dairy cattle are largely Holstein-Friesian, Guernsey, and Jersey, but many are crossbred. The better stock is on the dairy farms, and there are a few purebred bulls. Dairy products are consumed locally.

The few flocks of sheep in the area, chiefly of a Suffolk-Rambouillet cross, are raised for market. Hogs are kept on some farms for home consumption.

Farmers raise poultry on a commercial scale in the lower part of the area near the Double Adobe School, and the poultry is shipped to Douglas, Bisbee, and Tucson. White Leghorns are raised almost exclusively, but there are a few Rhode Island Reds and New Hampshires. A few ranchers raise turkeys.

Range ponies are being improved by thoroughbred and choice sires.

The numbers of livestock in Cochise County in stated years are given in table 3.

TABLE 3.—*Number of livestock in Cochise County, Ariz., in stated years*

Livestock	1930	1940	1950
	Number	*Number*	*Number*
Horses	3, 971	[1] 4, 687	2, 952
Mules	585	[1] 406	226
Cattle	92, 935	[1] 93, 382	67, 252
Sheep	9, 740	[2] 6, 794	1, 952
Goats	7, 157	[3] 2, 045	225
Swine	1, 215	[3] 1, 937	1, 579
Chickens	[1] 59, 068	[3] 57, 200	[3] 37, 239
Turkeys	[5] 12, 702	[5] 8, 047	[6] 5, 047
Beehives	2, 503	4, 224	([4])

[1] Over 3 months old.
[2] Over 6 months old.
[3] Over 4 months old.
[4] Not reported.
[5] Turkeys raised previous year.
[6] Turkeys raised 1949.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of examining, classifying, and mapping o soils in the field. The soil scientist walks over the area at intervals not more than one-quarter mile apart and bores into the soil with an auger or digs holes with a spade. Each such boring or hole shows the soil to consist of several distinctly different layers, called horizons, which collectively are known as the soil profile. Each of these layers is studied carefully for the things about it that affect plant growth.

The color of each layer is noted. There is usually a relationship between the darkness of the color of the surface layer of soil and its content of organic matter; streaks and spots of gray, yellow, and brown in lower layers commonly indicate poor drainage and poor aeration.

Texture—the content of sand, silt, and clay in each layer—is determined by the feel of the soil when rubbed between the fingers and is checked by mechanical analyses in the laboratory. Texture determines to a considerable extent the quantity of moisture the soil will hold available to plants, whether plant nutrients or fertilizers will be held by the soil in forms available to plants or will be leached out, and the difficulty or ease of cultivating the soil.

Soil structure, or granulation, and the number of pores or open spaces between soil particles determine the permeability or perviousness of the soil; and, consequently, the ease with which plant roots penetrate the soil and water enters it.

Consistence, or the tendency of the soil to crumble or to stick together, determines the degree of difficulty that will be encountered in keeping the soil open and porous under cultivation. Consistence covers such soil characteristics as hardness, friability, plasticity, stickiness, compactness, toughness, and cementation.

Surface soil ordinarily refers to the surface layer. The layer just below the surface soil is the subsoil; the layer beneath the subsoil, the substratum.

The kind of rocks and the parent soil material that develops from these rocks affect the quantity and kind of plant nutrients found in the soil. Simple chemical tests are made to show the degree of acidity of the soil; and the depth to bedrock or to compact layers is determined. The quantity of gravel or rocks that may interfere with cultivation, the steepness and kind of slope, the quantity of soil lost through erosion, and other external features are observed.

On the basis of all these characteristics, soil areas much alike in the kind, thickness, and arrangement of layers are mapped as one soil type. Some soil types are separated into two or more phases. For example, if a soil type has slopes ranging from less than 1 to 3 percent, the type may be mapped in two phases, a nearly level phase (less than 1-percent slopes) and a very gently sloping phase (1- to 3-percent slopes). A soil that has been eroded in places may be mapped in two phases—an uneroded phase and an eroded phase. A soil type is divided into phases primarily because of differences in the soil other than those of kind, thickness, and arrangement of layers. The slope of a soil, the frequency of outcropping bedrock, erosion, or the artificial drainage used on the soil, for example, are characteristics that might cause a soil type to be divided into phases.

Two or more soil types may have similar profiles; that is, the soil layers may be nearly the same except that the texture of the surface layer may differ. As long as the other characteristics of the soil layers are similar, these soils are considered to belong in the same soil series. A soil series therefore consists of all soil types, whether the number be only one or several, that are, except for texture of the surface layer, about the same in kind, thickness, and arrangement of layers.

The name of a place near where a soil series was first found is chosen as the name of the series: thus Hooker is the name of a deep, moderately permeable, neutral soil series found on flood plains where medium-textured to moderately fine-textured material has been deposited. Two types of the Hooker series are found—Hooker clay loam and Hooker sandy loam. Each of these soil types has a different surface soil texture, as their names indicate. Hooker clay loam and a phase of Hooker clay loam have been recognized. The phase—Hooker clay loam, eroded—differs from Hooker clay loam in that the surface soil has been cut by numerous shallow stream channels or gullies.

When small areas of two or more kinds of soil are so intricately mixed they cannot be shown separately on a map of the scale used, they are mapped together, and the areas of the mixture are called a soil complex. Elfrida-Gothard loams is a complex of Elfrida loam and Gothard loam.

Areas of dune sand that have little true soil are not designated with series and type names but are given the descriptive name, Dune sand (partially stabilized). Gravel pits are not given a name but are shown on the map by symbol.

The soil type—or, where the soil type is subdivided, the soil phase—is the mapping unit in soil surveys. It is the unit, or the kind of soil,

that is most nearly uniform and has the narrowest range of characteristics. For this reason, land-use and soil-management practices can be more definitely specified for it than for broader groups of soils that contain more variation.

The naming of soil series is a part of a nationwide program of soil classification that has been carried on by the U. S. Department of Agriculture and State Agricultural Experiment Stations since 1899. In the National Cooperative Soil Survey program, the same soil is given the same name wherever it has been found. The process of assigning the names is called soil correlation. It requires that the soils of the survey area be studied by soil scientists who are familiar with the soils of other areas. The end result is that any soil type—Briscoe loam, for example—is essentially the same soil and has similar management problems wherever it is mapped.

This process of soil correlation is basic to the rapid interchange of information on soil use from one area to another. Obviously, it is impossible to conduct experiments on soil-use practices on every soil in every survey area. But where the similarities and differences in the soils of different areas are brought out in soil correlation, the results of experiences on soils in one area can be applied to similar soils in other areas.

The system of soil classification has been steadily modified to keep pace with the development of new information about soils and their management. In the early surveys, the series were broadly defined. New developments have sometimes revealed important differences between members of the same series. In such cases the series is divided into two or more series, in order that the information on soil use can be applied with the greatest precision. Thus the newer soil survey maps commonly are more detailed and recognize more soil series than the older maps.

SOILS

In the Sulphur Spring Valley, only semidesert types of vegetation, including a wide variety of grasses and shrubs, can survive under natural conditions, except along stream courses or in basins where floodwaters settle. Soil characteristics greatly influence the supply of moisture available to plants, the feasibility of irrigation, and the yields obtained from the use of the limited supply of irrigation water.

These soils have developed many of their dominant characteristics under the warm semidesert environment. They are relatively low in organic matter and nitrogen, but they contain more than the soils of the lower desert valleys. They are rich in the relatively soluble mineral compounds, such as lime carbonate and gypsum. Some of the soils are saline or alkaline in character; they contain injurious quantities of the ordinary soluble salts found in the area. Phosphorus is usually present in sufficient quantity for limited normal plant growth, but it may be rendered unavailable in the more calcareous soils.

In general, the soils are fairly light-colored because of the relatively low organic-matter content and somewhat reddish because of the high degree of oxidation and lack of hydration of the iron compounds. Soils that have been undisturbed long enough to have formed definite surface and subsoil layers are free of lime carbonate in the surface

soil to variable depths, but subsoil accumulations of this and other soluble compounds are common to most of the soils. The subsoil in many places is very hard and in others is cemented into a lime hardpan (caliche). These caliche layers may have formed by the evaporation of lime-charged water in the subsoil. In most of the older soils, a reddish-brown, hard, clayey subsurface or upper subsoil layer occurs over this limy horizon. Where alkali conditions prevail, sodium clay often makes these clayey layers tight and impervious.

Aside from areas where grass is dense or where comparatively dark organic silts have been deposited, organic residues from the vegetation have not significantly modified or masked the parent soil materials. Differences in the soils are determined largely by the texture and mineralogical composition of the parent materials; yet significant changes have developed during the time these materials have been exposed to weathering and soil-forming forces. Important characteristics, including the calcium and the sodium content of the soils and colloids, have resulted from differences in drainage and moisture conditions.

The soil materials have accumulated on alluvial fans and flood plains where the mineralogical composition often is considerably mixed, owing to derivation from varied rocks. Both their composition and texture are closely related to their distance from the source of rock. The farther these soil materials have been transported, the finer textured they are, and the greater is the possibility of mixture with material from other sources. Relatively unmixed coarse-textured materials from a single parent rock occur well up on the alluvial-fan slopes, whereas the finer-textured materials of varied mixed origin occur on the lower slopes and alluvial plains. Some of the more recent alluvium in part owes its relatively high organic-matter content to the darker soils of the higher grasslands and woodlands from which it was eroded. Older, less pervious soils lie buried under these dark sediments in places.

Deficiencies in organic matter and nitrogen can be corrected by use of alfalfa or other leguminous crops in proper rotation and by incorporation of crop residues, manure, and fertilizer. These practices and the maintenance of good tilth increase availability of phosphorus, but applications of soluble phosphate fertilizer are often advisable on the highly calcareous soils. Many soils have certain inherent defects, such as coarse texture, excessive porosity, low water-holding capacity, dense imperviousness, hardpan, excess salts, and high alkalinity, that are difficult or impossible to remedy. Such soils are not considered well suited to irrigation.

Characteristically, in these valley basins, poor soils with high salt content or with tight moderately impervious subsoils or hardpan lie in the belt where water is at shallow depth and where it can be pumped at least cost. About 27 percent of the soils of the area are affected by toxic quantities of salts, some of which are highly alkaline. In many places these soils are underlain by hardpan or plastic clay. Soils in this lowland belt support fair to moderate stands of grass and browse and are valuable for grazing but have questionable value for cultivated crops. Some areas once cultivated have been abandoned and are now used for grazing.

Outward from this lowland belt, the ground water becomes gradually farther from the surface with the increasing elevation of the alluvial fans, and the soils are not charged with toxic salts. Lime hardpan and tight subsoils are less common here, although in both the Willcox Division and Kansas District soils with considerable hardpan or very limy subsoils occur well up on the alluvial fans and old stream deltas. In the area surveyed, the depth to water varies from about 20 to 120 feet. Pumping is expensive on the outer rim; therefore, a large number of farms are situated on soils adjacent to the lower and more saline parts of the area. With the exception of a few areas having toxic quantities of salts or underlying hardpan or both, this intermediate belt coincides fairly well with the region of soils best suited to farming. On the outer rim above and beyond this, the soils are frequently coarser in texture, droughty, and of more irregular relief. Many areas on the steeper slopes are subject to accelerated erosion and are traversed by numerous ephemeral streams that alternately cut and fill.

SOIL SERIES, TYPES, AND PHASES

In the following pages the soils of the area are described in detail and their agricultural relations are discussed. Their location and distribution are shown on the soil map that accompanies this report, and their approximate acreage and proportionate extent are given in table 4.

TABLE 4.—*Approximate acreage and proportionate extent of soils mapped in the Sulphur Spring Valley area, Ariz.*

Soil	Whitewater Division		Kansas District		Willcox Division	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Briscoe gravelly sandy loam:						
Nearly level	-------	-------	-------	-------	288	0. 6
Very gently sloping, eroded	-------	-------	-------	-------	176	. 4
Briscoe loam	1, 795	1. 8	-------	-------	-------	-------
Deep over Forrest soil material	88	(1)	-------	-------	-------	-------
Briscoe sandy loam:						
Nearly level	6, 300	6. 4	1, 979	9. 4	1, 152	2. 5
Hummocky	-------	-------	167	. 8	-------	-------
Cogswell sandy clay loam	-------	-------	30	. 1	1, 733	3. 8
Cogswell sandy loam	-------	-------	-------	-------	1, 643	3. 6
Continental gravelly sandy loam	2, 690	2. 7	11	. 1	235	. 5
Continental sandy clay loam	324	. 3	390	1. 8	1, 419	3. 1
Eroded	-------	-------	100	. 5	373	. 8
Continental sandy loam	2, 669	2. 7	-------	-------	270	. 6
Courtland loamy coarse sand	4, 819	4. 9	-------	-------	-------	-------
Eroded	2, 439	2. 5	-------	-------	-------	-------
Cowan loamy coarse sand	356	. 3	-------	-------	1, 111	2. 4
Duncan loam	-------	-------	43	. 2	3, 772	8. 2
Dune sand (partially stabilized)	-------	-------	42	. 2	26	(1)
Elfrida clay loam	3, 630	3. 7	2, 286	10. 8	1, 745	3. 8

See footnote at end of table.

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TABLE 4.—*Approximate acreage and proportionate extent of soils mapped in the Sulphur Spring Valley area, Ariz.*—Continued

Soil	Whitewater Division		Kansas District		Willcox Division	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Elfrida-Gothard loams	5, 712	5. 8	-------	-------	-------	-------
Elfrida sandy clay loam	6, 394	6. 5	948	4. 5	2, 823	6. 1
Elfrida silty clay loam	13, 510	13. 7	-------	-------	647	1. 4
Forrest clay	420	. 4	-------	-------	-------	-------
Forrest clay loam	1, 924	2. 0	-------	-------	251	. 5
Forrest gravelly sandy loam	-------	-------	-------	-------	181	. 4
Forrest sandy clay loam	6, 090	6. 2	-------	-------	679	1. 5
Hummocky	2, 425	2. 5	-------	-------	-------	-------
Frye sandy clay loam	-------	-------	187	. 9	1, 913	4. 2
Frye sandy loam	-------	-------	306	1. 4	908	2. 0
Gothard sandy clay loam	3, 706	3. 8	881	4. 2	2, 326	5. 1
Gothard sandy loam	-------	-------	1, 636	7. 7	3, 477	7. 6
Hooker clay loam	2, 628	2. 7	177	. 8	4, 366	9. 5
Eroded	-------	-------	-------	-------	160	. 3
Hooker sandy loam	6, 013	6. 1	-------	-------	213	. 5
Karro sandy loam	2, 383	2. 4	1, 018	4. 8	1, 666	3. 6
Hummocky	-------	-------	18	. 1	180	. 4
Karro loam	811	. 8	2, 698	12. 8	691	1. 5
Karro loamy sand	-------	-------	455	2. 2	65	. 1
Hummocky	-------	-------	1, 316	6. 2	-------	-------
Kelton loamy sand	91	. 1	-------	-------	-------	-------
Hummocky	949	1. 0	-------	-------	-------	-------
McAllister sandy clay loam	72	(1)	-------	-------	1, 608	3. 5
McAllister sandy loam	-------	-------	-------	-------	3, 952	8. 6
McAllister loamy sand	-------	-------	-------	-------	151	. 3
Hummocky	-------	-------	-------	-------	57	(1)
McNeal sandy loam	9, 814	10. 0	-------	-------	-------	-------
Mimbres clay loam	-------	-------	3, 065	14. 5	822	1. 8
Mimbres loam	-------	-------	2, 469	11. 7	927	2. 0
Riggs clay	4, 410	4. 5	-------	-------	-------	-------
Riggs clay loam	843	. 9	4	(1)	-------	-------
Rucker gravelly sandy loam	2, 704	2. 7	753	3. 6	692	1. 5
Rucker sandy loam	1, 795	1. 8	18	. 1	31	(1)
Sonoita sandy loam	439	. 5	102	. 5	653	1. 4
Stewart loam	-------	-------	-------	-------	673	1. 5
Stewart sandy loam	-------	-------	21	. 1	2, 025	4. 4
Tubac sandy loam	317	. 3	-------	-------	-------	-------
Total	98, 560	100. 0	21, 120	100. 0	46, 080	100. 0

[1] Less than 0.1 percent.

BRISCOE SERIES

The Briscoe soils occur in all three districts and cover a considerable area. They are situated on broad and narrow very gently sloping ridges and are usually slightly higher than Elfrida and other surrounding soils. They have developed from material of mixed origin, much of which is coarse- and medium-textured, but gravelly areas and ridges are common in some sections.

These relatively light-colored soils support a sparse cover of annual grasses and some perennials interspersed with flowering annuals and a scattering of Mormon-tea, yucca, and mesquite.

The Briscoe soils are not deeply leached but are mildly calcareous

at or near the surface. They have a very pale-brown, pale-brown, or light-brown surface soil over a similar colored, very friable, stratified subsoil. Slight to moderate accumulations of light-gray lime are found in the lower subsoil. The moisture-holding capacity is moderately low.

As range land, these soils have low carrying capacity and afford only seasonal grazing. Most crops do exceptionally well on irrigated areas. The water requirement is relatively high, but the cost of pumping is not excessive where ground water is comparatively close to the surface. Electric power is available through the rural electrification program.

Briscoe sandy loam, nearly level (0–1% slopes) (BF).—This soil, the most extensive of the Briscoe series, is widely distributed, mostly on slightly elevated or smooth ridges (pl. 1, *A*) in association with Elfrida, McNeal, McAllister, and Continental soils of the basins and smoother areas.

The 6- to 12-inch surface soil is pale-brown or light-brown to very pale-brown, very friable sandy loam. It is noncalcareous and slightly massive in place but breaks out as weakly defined medium to fine granules. The upper subsoil (12 to 45 inches) is slightly lighter colored sandy loam or loam with some slight compaction and slight accumulation of well-disseminated lime in the lower part. Fine gravel may occur. Below this are very pale-brown or light yellowish-brown somewhat coarser textured sandy strata that are mildly to strongly calcareous. These materials are generally loose and contain disseminated lime.

The gravel content varies considerably from place to place. It is greatest on the more prominent ridges that are scattered throughout most areas of this soil. The gravel reduces the already moderately low moisture-holding capacity. Furthermore, gravelly areas are generally less favorable for water distribution.

Included are areas in which the soil has slight differentiation of profile layers. The subsoil in places is a heavy loam or clay loam showing a weak to moderate granular structure. This characteristic, however, is variable in short distances and pertains particularly to the areas east of Elfrida. In other areas the lower subsoil (below 48 inches) is exceedingly variable, ranging from mildly calcareous very coarse-textured material to highly calcareous medium-textured material. The gravelly areas are shown by symbol. Many areas in the southeastern part of the Willcox Division are darker colored and coarser textured in the subsoil than normal. Areas occurring in the narrow or elongated ridges are generally of more shallow and strongly calcareous material and have greater variations in texture and consistence. The areas associated with the Continental soils in the northern and western parts of the Whitewater Division are browner in color, more porous, and much less calcareous.

The material from which this soil developed includes material from rhyolite, quartzite, and limestone and was laid down as alluvial fans and low smooth ridges extending well out into the valley. In these positions surface runoff is slow to medium, and internal drainage is rapid to medium. Erosion is limited, but some wind-formed hummocks occur around shrubs.

Use and management.—Most of this soil has never been cultivated and supports thin stands of annual and perennial grama, galleta grasses (*Hilaria rigida* and *H. jamesii*), scattered yucca, Mormon-tea, and mesquite. Fluffgrass and flowering annuals grow in the more gravelly and droughty places. The carrying capacity for grazing is low and is best during seasons when the annuals are growing.

Cultivated areas are used largely for alfalfa, beans, fruits, cotton, chili, and garden vegetables, and yields are good. The cultivated acreage occurs largely where the ground water lies comparatively close to the surface.

This soil is low in organic matter and nitrogen. Short rotations that include alfalfa or other legumes are needed to maintain productivity. Plowing under such green-cover crops as sour clover and incorporation of crop residues and manure will increase the organic content and will help to keep phosphates available for plants. As the supply of lime is probably sufficiently high to have some adverse effect on the availability of phosphates, the addition of soluble phosphates may be needed to obtain the highest yields from some crops.

Briscoe sandy loam, hummocky (0–1% slopes) (BE).—This soil is very similar to the nearly level phase. It differs mainly in that wind erosion has removed 2 or 3 inches of surface soil in places, and numerous hummocks, ranging up to 36 inches, occur where sand or loamy sand has accumulated around clumps of mesquite and other bushes. The soil is inextensive and none is cultivated.

Use and management.—Vegetation consists almost entirely of mesquite with some fourwing saltbush. The carrying capacity is low but could be improved by seeding range grasses and deferring grazing until they have become well established. The hummocks would interfere somewhat with clearing and leveling for irrigation.

Briscoe gravelly sandy loam, nearly level (0–1% slopes) (BA).—Its content of rounded pebbles is the main characteristic distinguishing this soil from the sandy loam. The surface soil usually contains about 20 percent rhyolite pebbles that are ¼ to 1½ inches in diameter. The quantity of pebbles usually increases, and below 24 inches it is approximately 40 percent. The subsoil consists of strata that range widely in proportion of gravel, sand, and sandy loam. The pebbles usually have white lime coatings on their lower sides. Erosion is noticeable in overgrazed areas. A very striking example is the 12-acre tract in sec. 2, T. 13 S., R. 24 E. Sand hummocks around clumps of mesquite in that area are dominantly more than 36 inches high.

Use and management.—This soil occupies small areas in the Willcox Division and is used only for grazing. The grazing value is fair to low, depending upon the stand of grass. Some areas support a moderate stand of galleta grass, mesquite bushes, and trees; in other areas, overgrazing has almost obliterated the grass.

Briscoe gravelly sandy loam, very gently sloping, eroded (1–3% slopes) (BB).—Areas of this soil occur at the western margin of the Willcox Division. Gullies are commonly 6 to 24 inches deep and 12 to 15 inches wide. In some places the soil material cut from the channels has accumulated on the surface of this phase at lower eleva-

tions. In other places it has been carried farther and deposited on other soils of the area.

Use and management.—This soil is used for grazing but has a low carrying capacity. Because of overgrazing and erosion, mesquite trees and annual weeds provide most of the forage. It would be expensive to control erosion on these slopes, but reseeding, controlled grazing, and water spreading would improve carrying capacity.

Briscoe loam (0–1% slopes) (Bc).—This soil is much like Briscoe sandy loam, nearly level, except for having fine-textured surface soil and subsoil. It is much less extensive and occurs in the southeastern part of the Whitewater Division. It occupies similar positions, but the surface is smoother in many places and contains a number of small basins (see pl. 1, *A*). Small gravel ridges are common. The vegetation differs from that on the sandy loam only in the occurrence of tobosa in the basins and along the outer margins.

In a typical location, this soil has a 12-inch surface soil of pale-brown or grayish-brown friable loam or sandy loam that breaks into medium to fine granules and in places is very mildly calcareous. The upper subsoil, extending from 12 to 23 inches, is pale-brown friable heavy loam or clay loam, somewhat harder than the surface soil and with a weakly to moderately defined medium granular structure and a slightly hard consistence. This is underlain to depths of 30 inches by stratified materials of very pale-brown sandy loam, loamy sand, or sand containing lime-coated gravel. The substratum is grayish-brown calcareous heavy silty clay loam interstratified with sandier materials. The parent material is similar to that of the sandy loam.

Use and management.—The carrying capacity of this soil is slightly greater than that of Briscoe sandy loam, nearly level. It is suited to a slightly wider range of crops because of its finer texture and greater water-holding capacity. Nevertheless, little of it is cultivated.

Briscoe loam, deep over Forrest soil material (0–1% slopes) (Bd).—This soil occurs in an area about 3 miles west of the Double Adobe School. It is near the lower margin of alluvial fans, where the slope gradient is low. The area has been flooded by drainage waters that have caused considerable sheet and gully erosion on the adjacent Forrest soils and on steeper soils immediately to the west. The surface, which is slightly undulating owing to shallow gullies and low hummocks, has a general eastward slope. The vegetation is largely mesquite and acacia with some sacaton grass and annual weeds. About 25 percent of the surface is barren most of the year.

The soil consists of about 36 inches of comparatively recent alluvium superimposed over soil material similar to that of adjacent Forrest soils. Parent rocks for the upper soil are similar to those of the Forrest series—quartzite, limestone, and shale. The surface soil and upper subsoil are light-brown, mildly calcareous, friable loam or silt loam, readily permeable to water and plant roots and moderate in water-holding capacity. This upper alluvium is underlain by reddish-brown, moderately compact, hard silty clay loam that offers some resistance to penetration of water and plant roots. Internal drainage is slow but adequate. Considerable leveling of the surface is required for irrigation, and dikes are essential for flood protection.

Use and management.—This soil is used mainly for range. The carrying capacity is low but could be increased by spreading runoff from adjacent higher areas and controlling grazing. The soil is well suited to irrigation, especially for the more shallow-rooted crops.

COGSWELL SERIES

The Cogswell soils occur only in the Willcox Division, predominantly in the low basins and depressions in close association with the McAllister, Elfrida, and Frye soils. Periodic flooding is common in these low positions; and though water does not remain for extended periods, the soil stays highly saturated for days after a heavy rain. This moisture promotes a luxuriant stand of grass and other vegetation, causing the Cogswell soils to be darker, higher in organic matter, and less eroded than soils of the Frye or McAllister series.

In most areas the surface soils cannot be distinguished from those of the Hooker soils, which occupy similar basins and depressions. Barren slick areas are common to both series. These slick areas appear to be caused partly by the fine-textured sediments that bake and become hard on drying, for the areas in which they occur usually have neither high salt content nor high alkalinity. Some barren areas adjacent to the lower basins, however, contain considerable salt. In these locations the barren spots are probably caused by high content of exchangeable sodium, because strong alkalinity is not uncommon. These areas have slower surface and internal drainage than those elsewhere.

Water usually can be obtained 20 to 70 feet below the surface. Because of adverse saltiness or other physical conditions, it is important that the map be used as a guide when selecting areas of Cogswell soils for cultivation.

Cogswell sandy loam (0–0.5% slopes) (Cʙ).—The fine-textured, mixed alluvial materials from which this soil developed are from varied sources outside the surveyed area and occur largely on smooth level areas and in low basins or in depressions along ill-defined drainageways. These areas are flooded during rainy periods, and often considerable dark sediment is deposited. This soil is widely distributed throughout the Willcox Division.

The 3- to 5-inch surface layer is noncalcareous, pale-brown, vesicular, platy loam that is grayish brown, dark grayish brown, or brown when moist. The lower surface soil is brown, noncalcareous or mildly calcareous, coarse granular, friable heavy sandy loam or sandy clay loam to a depth of 12 inches. Some areas are moderately calcareous from lime-impregnated floodwaters. The upper subsoil, extending to 24 inches, is brown heavy sandy clay loam that is hard and very weakly prismatic, spotted and veined with lime, and easily broken into coarse granules or fine blocks. From 24 down to 30 inches is more highly calcareous and massive material containing some small lime-carbonate nodules. This layer changes abruptly to a cemented lime layer of fragmental plates closely packed at the top but alternated with softer, light-gray, iron-stained materials of variable thickness below. The substratum includes thick caliche layers and extends to undetermined depths. The depth to hardpan varies from 2 to 4 feet in short distances, and in some places it is not present as far down as 5 feet.

A few areas occupy slightly higher positions and are lighter colored, more friable, and in places calcareous to the surface. These areas are not so frequently flooded, and vegetation is less dense.

Use and management.—Under range conditions the grass and browse furnish good grazing. Some tobosa grows, but sacaton and burrograss predominate. Dense thickets of mesquite and a scattering of acacia, hairy squawbush and crucifixion-thorn (*Holacantha*) occur.

Most of this soil is free from adverse salinity and alkalinity and is well suited to cultivation, but only a small percentage is farmed. The principal crops are alfalfa, small grains, hegari, cotton, and beans.

Irrigation water usually can be reached at 30 to 75 feet. Electric power is available in most places under the rural electrification program.

Owing to the general fragmental character of the lime hardpan, roots and water are impeded only where the indurated hardpan is thick and dense or where it occurs at shallow depths. For the most part, good yields are obtained where good management and careful irrigation are practiced. Barren spots can be improved by the application of manure and crop residues. Gypsum is recommended where a high sodium content exists. The treatment of affected areas depends on the cause of the poor physical condition. Because nutrients other than phosphorus seem to be plentiful, rotations that include legumes to supply organic matter and nitrogen should maintain a high level of productivity. Soluble phosphates are especially valuable for alfalfa.

Cogswell sandy clay loam (0–0.5% slopes) (Ca).—The materials from which this soil developed are fine-textured sediments of mixed origin that have become masked in the surface soil by considerable organic matter from decaying organic residues and by some dark organic sediments from outside sources.

In the Willcox Division this soil is intimately associated in the lower basins or depressions with Cogswell sandy loam, and except for surface soil texture has similar characteristics. It usually occurs in the lower positions, and water moves off more slowly but does not remain for extended periods. Though the upper soil becomes highly saturated after rains, internal drainage is sufficient to prevent waterlogging. Near the lower salty basins, however, drainage is retarded to the extent that considerable salt has accumulated and alkali slick spots may occur. Elsewhere on this soil, such spots appear to be caused largely by poor physical condition but may result from the presence of sodium clay.

Use and management.—Tobosa, sacaton, burrograss, dense growths of mesquite, and a scattering of acacia, hairy squawbush, and crucifixion-thorn provide good grazing and browse.

Less than 25 percent of this soil is cultivated. The crops and their yields are similar to those on the sandy loam. The same care is necessary in soil management and irrigation. The hardpan is equally variable in depth and density, and management may need to be adjusted to this condition.

CONTINENTAL SERIES

Most of these soils occur in the northern part of the Whitewater Division as large bodies on broad smooth alluvial fans sloping very gently to the valley floor. Elsewhere, they are scattered as small bodies well up on alluvial fans skirting the outer limits of the survey. They are from materials in which rhyolite predominates and typically have deeply leached, well-defined reddish-brown or red, plastic, colloid-stained subsoils showing slight lime accumulation at the lower limits. The added moisture from runoff has promoted distinct subsoil differentiation, deep leaching of calcium carbonate, and deeper leaching of the more soluble salts.

These soils support grass, mainly in the northern part of the Whitewater Division, but a scattered stand of mesquite, yucca, and Mormon-tea is not uncommon. Perennial grama grasses, three-awn, and feathergrass provide the most palatable grazing. Annual grasses and Indian-wheat supply some seasonal grazing. Only a small acreage is farmed. Water occurs generally at a depth where cost of pumping would be high.

Continental sandy loam (0–1% slopes) (CF).—This soil occupies smooth, gently sloping alluvial fans. The 6-inch surface soil is brown or reddish-brown, medium to fine granular, very friable sandy loam with a thin, vesicular, gravelly surface crust. From 6 inches down to 18 inches is reddish-brown to yellowish-red, plastic, gritty clay loam in which vertical fractures produce indistinct prisms or strongly differentiated blocky aggregates that are very hard when dry. From 18 inches down to 26 inches is noncalcareous slightly lighter reddish-brown clay loam or clay that breaks into large irregularly shaped very hard blocks. Some gravel is embedded in the lower part. At a depth of about 38 inches begins pink plastic clay or clay loam with a large number of embedded round rhyolite pebbles. This layer is flecked with lime in its upper part and becomes strongly mottled and almost white in the lower part. From 38 inches down to 60 inches or more is pink massive gravelly sandy loam.

In the Whitewater Division, where most of it occurs, this soil is more deeply leached than elsewhere. The thickness of the surface soil and the content of gravel are variable. Sheet erosion has kept the surface soil somewhat shallow in most places, but there are only occasional gullies. Erosion is most active on the upper fans, where the slope is slightly greater.

The lay of the land in most places is well suited to water distribution. Drainage is rapid in the surface, slow in the fine-textured subsoil, and rapid in the gravelly substratum. Roots penetrate the subsoil with difficulty; and though large quantities of moisture are absorbed, much of it is not readily available to plants in times of drought. These conditions are especially severe where the surface soil is shallow; and, because of this, the soil is only moderately well suited to irrigation.

Use and management.—This soil is used chiefly for range land and has a fair to low carrying capacity. The vegetation is grama and galleta grasses, mesquite (pl. 1, *B*), yucca, Mormon-tea, broomweed, annual grasses, weeds, and herbs. Some areas are severely overgrazed.

Continental sandy clay loam (0–1% slopes) (CD).—This soil is associated with other Continental soils and with Tubac sandy loam in widely scattered small acreages on the upper part of the fans. Continental sandy clay loam is similar to Continental sandy loam except in surface texture. Surface texture varies from sandy loam to sandy clay loam in short distances, owing to erosion and deposition.

Use and management.—The soil has the same use as Continental sandy loam. None of it is cultivated. It should be used principally for grazing, as it has a fine-textured subsoil not especially well suited to irrigation and occurs mostly on comparatively high parts of the fans where pumping for irrigation would be costly. Some areas are severely overgrazed. Controlling grazing and spreading runoff are recommended.

Continental sandy clay loam, eroded (0–1% slopes) (CE).—Many small bodies of this soil occur in the Willcox Division, and a very small acreage is in the Kansas District. The soil occurs in the same relative position as the uneroded soil but where runoff has cut a number of gullies that are usually less than 12 but may be 18 to 24 inches deep. Sheet erosion has destroyed most of the grass.

Use and management.—The vegetation consists of a moderate to sparse stand of mesquite and annual weeds. The soil is used only for grazing. The fair to low carrying capacity could be improved by structures that would spread runoff rather than permit it to cut gullies. Structures adequate to accomplish this, however, would be expensive.

Continental gravelly sandy loam (0–1% slopes) (CC).—A gravelly surface and less depth to the gravelly subsoil are the differences between this soil and Continental sandy loam. Usually the gravelly and cobbly subsoil has a stronger accumulation of lime and in places it consists of a softly to moderately hard lime-cemented hardpan.

Use and management.—This soil is not well suited to irrigation. It has unfavorable surface texture, fine-textured subsoil, and comparatively shallow depth to the gravelly and cobbly subsoil and substratum.

The soil is used for grazing. The vegetation consists of a sparse stand of mesquite and broomweed and an extremely sparse growth of needle grama, other grama grasses, and annual weeds. The carrying capacity is very low in the overgrazed areas. Controlling grazing and reseeding to recommended range grasses would improve the carrying capacity.

COURTLAND SERIES

Soils of the Courtland series—the loamy coarse sand and its eroded phase—are largely west of Whitewater Draw in the northwestern part of the Whitewater Division. Smaller areas occur near the eastern border of this district.

The soils are on alluvial fan materials that largely came from granites and related rocks deposited on very gentle slopes. Runoff from outside sources pours over the fans and accentuates sheet erosion and gullying. Floodwater deposits of alluvium are common, and wind-blown sands may accumulate as low hummocks around the brush vegetation.

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Surface runoff and internal drainage are slow. The moisture-holding capacity is moderately high. Ground water occurs at depths of 60 to 100 feet or more, and lifting water for irrigation is more expensive than for soils lower in the valley.

The native vegetation is dominantly mesquite, needle grama, blackbrush, and annuals. A large part of the surface is barren except following rains, when annual weeds and grasses are prominent. Sacaton, grama grass, and occasionally yucca occur. The grazing capacity is low.

Only a small acreage is cultivated. If these soils were farmed and well managed, they probably would produce good yields of fruits, alfalfa, beans, and root vegetables. Leveling, however, would be expensive in many areas.

Courtland loamy coarse sand (0–2% slopes) (CG).—The 12-inch surface soil consists of noncalcareous reddish-brown friable loamy coarse sand crusted with light-brown vesicular plates over which a sprinkling of granitic sand or fine angular gravel usually occurs. Noncalcareous reddish-brown plastic sandy clay loam or heavy loam is at 12 to 22 inches. It is hard when dry and massive to weakly prismatic. Coarse sand and small angular pieces of gravel are prominent in this layer. Between 22 and 40 inches, the material is red gritty clay or sandy clay, strongly fine prismatic, hard to very hard, and usually slightly calcareous in a few seams near the lower limits. Below 40 inches and continuing to 60 inches are stratified layers of yellowish-red sandy clay loam bedded with clayey coarse sand and clayey angular fine gravel. These are bound by colloids, silica, and iron, but hard caliche layers are usually not encountered at less than 6 to 8 feet below the surface.

Irrigation water needs to be applied often but in comparatively small quantities. The clay subsoil has a high water-holding capacity, but the water is held so tightly that it is difficult for plants to obtain it. The soil is so low in organic matter and phosphorus that most irrigated crops should respond favorably when they are added.

Courtland loamy coarse sand, eroded (0–2% slopes) (CH).—Although similar to the uneroded Courtland loamy coarse sand in occurrence and profile characteristics, this soil is cut by shallow gullies that have been made by runoff from adjacent higher fans. The water has deposited sediments near the places where the gullies terminate. Such erosion has given rise to variations in the thickness of the friable surface soil or in the depth to fine-textured material in the subsoil. This depth ranges from a few inches to about 36 inches and is least where erosion has been most severe. The areas that have the deeper surface soil, or those where aggrading conditions have occurred, are near the lower margin of the Courtland soils on the western part of the Whitewater Draw.

Use and management.—This phase is used for range. It has about the same vegetative cover as the other Courtland soil, but erosion has lowered the carrying capacity. If this soil were reclaimed, considerable expense would be required to level it and to construct dikes for protection from floods.

COWAN SERIES

The Cowan soil—Cowan loamy coarse sand—occurs in widely distributed small bodies on the delta plains adjacent to Hookers Draw and west of Whitewater Draw. It is mostly on long narrow ridges, generally smooth but in places very gently undulating. Some areas west of Whitewater Draw are on smooth alluvial fans. The parent materials are chiefly from granite, granodiorite, and related rocks and contain much coarse angular sand, largely quartz. Nevertheless, bedding with fine gravel is not uncommon.

Annual grasses and flowering annuals are the chief native vegetation, but yucca and scattered mesquite occur in many places. A few of the less droughty situations have a sparse stand of perennial grama grasses.

Distinguishable soil layers are largely absent in this stratified soil, and little or no lime has accumulated in the subsoil. The coarse porous texture permits deep aeration and oxidation, and the soil is brown to reddish brown throughout. The parent rocks can be readily identified throughout the profile.

Cowan loamy coarse sand (0–1% slopes) (Ck).—The 12-inch surface of this widely scattered soil is light-brown to brown, very friable, gritty, noncalcareous loamy coarse sand. From 12 to 30 inches is reddish-brown, noncalcareous light sandy loam or loamy coarse sand. When moist, this layer is slightly more coherent than the surface soil but it does not have any appreciable compaction. The material is massive, slightly hard, and contains much angular coarse sand. Slightly reddish brown interstratified loamy sand, sandy loam, and somewhat finer materials are at depths of 30 to 60 inches. Below 60 inches are loose thickly bedded coarse sands with occasional pebbles and feeble traces of lime. In places lime occurs in slightly higher concentration and at shallower depths.

West of Whitewater Draw, the parent materials include some quartzite. In this location variable quantities of small rounded or angular pebbles occur from place to place, and the surface texture varies from loamy sand to loamy coarse sand.

The relief is level, or smooth enough for efficient irrigation, although side slopes on a few of the long narrow ridges have comparatively greater relief. The water-holding capacity is very low, and frequent irrigations are required. As the soil absorbs rainfall very rapidly, erosion is of minor importance. Small sand hummocks have collected around the mesquite bushes in some areas.

Use and management.—The greater part of this soil is uncultivated and supports mostly annual grasses and flowering herbs with scattered mesquite and yucca (pl. 2). The carrying capacity is low.

The few small areas that are farmed are used largely for alfalfa and fruits. The water-holding capacity is very low, but crops do well when sufficiently irrigated. This soil is deficient in organic matter and nitrogen in most places; therefore, use of short rotations that include alfalfa or other legumes should be initiated, as well as plowing under of green crops, crop residues, and manure. Owing to the low content of lime, phosphate fertilizer is not needed so much as on the more calcareous soils. Some of this soil occurs at high elevations where pumping of water for irrigation may be prohibitive because of the high lift and the high water requirement.

DUNCAN SERIES

Duncan loam, the only Duncan soil mapped in the area, is the most extensive alkali soil with hardpan. It occurs almost entirely in the broad flat salty delta plain northwest of Willcox, where it is closely associated with the Gothard soils. This delta plain has no drainageways, and floodwaters spread out in broad sheets that flow southward in wide basins. Water stands for extended periods following rains, and high concentrations of salts have accumulated. Some natural leaching has taken place, but the subsoils are always highly charged with salts, and the soil is highly alkaline and dispersed throughout. Barren slick spots are numerous, and low hummocks and occasional ridges are not uncommon on the sandier areas. Ground water occurs at shallow depths.

Duncan soil has an alkali structure characterized by a brownish gray vesicular and platy surface horizon over a light-gray ashy layer. The ashy layer caps short, brown, colloid-stained columns, the lower limits of which are not clearly defined but consist largely of angular fragments. Beneath this is a thin, tough, lime-spotted layer overlying a fragmental, platy to massive, lime-cemented hardpan. Softer materials occur between the layers of hardpan.

Duncan loam (0–0.5% slopes) (Da).—The 2- to 6-inch surface soil is light brownish-gray or very pale-brown loam to sandy loam. Below this layer and continuing to 12 inches is columnar brown or light-brown clay loam or silty clay loam composed of finer angular aggregates that are highly colloidal and very hard. From 12 to 30 inches is lighter brown weakly prismatic silty clay veined and specked with white carbonate of lime. This ends sharply on a light-gray to white, platy, fragmental hardpan, which has softer interplates of marly materials. These plates are of variable thickness and are more closely spaced near the top. The hardpan ranges from less than an inch to more than 6 inches in thickness. It is underlain by pale-brown or light yellowish-brown, medium-textured, strongly calcareous material interstratified with thin layers of lime hardpan.

This soil has developed on alluvial materials derived largely from granite or related rock formations. The salty and alkaline conditions of the soil have been effective in producing the tough columnar layer and hardpan. Flooding is common, and water stands for extended periods because of the very slowly permeable sodium claypan and lack of sufficient gradient for effective drainage. Some natural leaching has carried away surface accumulations of salt, but toxic concentrations occur in the subsoil, and the soil is highly alkaline. Slick barren areas are numerous, and scattered low wind-blown hummocks may occur around the mesquite and other brush.

Use and management.—All but a few acres are used for range pasture. Fair grazing is provided by mesquite, fourwing saltbush, saltbush, and alkali sacaton. A scattering of hairy squawbush, crucifixion-thorn, and seepweed occurs in some sections.

Less than 10 percent of this soil is being reclaimed. Reclamation is difficult, and the cost may prove prohibitive in many places. Slightly affected areas should be the most readily reclaimed, but most areas contain moderate to strong concentrations. In reclaiming this soil, continuous leaching, ripping, turning under of organic

residues, and gypsum applications are necessary to reduce the sodium content and establish proper tilth.

DUNE SAND (PARTIALLY STABILIZED)

Dune sand (partially stabilized) (Db) occurs as scattered areas of high dunes (3 to 15 feet) near Willcox and near the western margin of the Kansas District. Parent rocks are largely mixed igneous. The 10-inch surface soil is very pale-brown to pale-brown mildly calcareous loose sand and fine sand. Below this are loose moderately to strongly calcareous very pale-brown sands. The small area near Willcox is fairly stable at present and supports a moderately dense stand of yucca. The sands are loose and shifting in the Kansas District, and there are only a few scattered yucca. This land type has little or no agricultural value.

ELFRIDA SERIES

The Elfrida soils are the most extensive in the area and have a larger percentage under cultivation than any other series. A small acreage of the Elfrida soils occurs both in the Willcox Division and in the Kansas District, but the greater part occurs in relatively large bodies widely distributed in the Whitewater Division. Areas are found in basins or flat places on the lower reaches of the alluvial fans and on smooth broad ridges that descend well into the valley plain.

Flooding is common, and dense grass and other vegetation have developed because of the comparatively abundant moisture. Owing to the smooth relief and thick vegetation, sheet erosion is very slight and gullies are infrequent. Because of the generally good underdrainage, however, surplus water seldom collects on or in the soil for extended periods, and only in the central valley trough is salt concentrated in toxic quantities. Water-holding capacity is high, and internal movement of water is medium.

The surface soil is brown to pale brown, the darker soil usually being finer in texture. The brown subsoil is spotted and streaked with accumulated lime, hard when dry but friable when moist, and readily permeable to water and plant roots. The parent materials, of mixed origin and fine texture, are frequently masked by considerable organic matter. Organic matter has accumulated in the surface soil because the vegetation is comparatively dense and possibly because supplemental plant residues are in the alluvium deposited. Elfrida soils differ from the associated McNeal soils in being less red and in being relatively free from gravel in the subsoil.

Elfrida silty clay loam (0–0.5% slopes) (Ed).—Most of this extensive soil occurs in the southern part of the Whitewater Division. It occupies large continuous flat basins supporting thick stands of tobosa (pl. 3, *A*).

Over the surface is a 1½-inch light brownish-gray to pale-brown, crusted, finely granular mulch of light clay loam or loam. Below this and continuing to 12 inches is brown to pale-brown noncalcareous silty clay loam with a moderate medium granular structure that crumbles readily into hard fine granules (pl. 3, *B*). This material is dark grayish brown to dark brown when moist. Roots and worm holes are abundant. The 12- to 24-inch upper subsoil is brown

mildly to moderately calcareous heavy silty clay loam to clay of moderate to strong fine blocky structure. It is hard, and in places weakly prismatic. At 24 to 36 inches, the material becomes abundantly spotted with lime, the aggregates become larger, and the color changes to very pale brown or light gray. At 36 inches begins light-gray to very pale-brown massive silty clay loam that contains white streaks and spots of lime and, in places, lime nodules.

In some of the tobosa flats, this soil is more deeply leached and darker than described above. Areas that have been covered with lime-bearing floodwaters may be calcareous in the surface soil. Where the soil is closely associated with the McNeal soils west of McNeal, it is redder than normal.

Though the flat basins in which this soil occurs are frequently flooded by drainage waters, the soil remains well stabilized because it has flat relief and a thick grass cover. Under cultivation, such floodwaters may be diverted by dikes or flooding may be encouraged to add to the moisture supply. Most areas have surface outlets and underdrainage sufficient to prevent them from becoming waterlogged. Salt accumulations, however, occur in places near the lower margins of the valley plain. The moisture-holding capacity is high. Internal drainage is medium to slow. Ground water is found at relatively shallow depths in most areas, and the cost of pumping is not excessive.

Use and management.—Tobosa, the principal vegetation, provides considerable grazing, but it is coarse, wiry, and not especially palatable.

The small cultivated acreage is used largely for alfalfa, hegari, cotton, chili, corn, beans, lettuce, cantaloups, onions, and other truck crops. Yields of truck crops are satisfactory, and small grains should do well.

This soil has only about 1.3 percent organic matter in the surface layer, but this is more than occurs in many of the lighter colored and coarser textured soils. Plowing under crop residues and manures and using alfalfa and other legumes in crop rotations will keep the supplies of organic matter and nitrogen needed for crop production at a relatively high level. Practices such as these are essential in maintaining proper tilth and satisfactory infiltration of irrigation water. Because any appreciable quantity of lime is absent to considerable depth, these practices probably will increase the amount of phosphate available for plant growth.

Elfrida clay loam (0–0.5% slopes) (EA).—A clay loam surface texture and a predominantly clay loam subsoil are the principal differences between this soil and Elfrida silty clay loam. This soil is not so extensive as the silty clay loam but is closely associated with it throughout the Whitewater Division on smooth nearly level slightly higher areas. Surface drainage is very slow, and internal drainage is medium. Sheet erosion is very slight, and there is little gullying. Wind-blown sand sometimes accumulates around the mesquite bushes.

Use and management.—Toward the central part of the area, mesquite is the principal vegetation on this soil. Elsewhere, scattered tobosa and occasional quantities of yucca and Mormon-tea supplement the mesquite. The grazing value is fair.

Only a small acreage is used for cultivated crops. Crops grown, cultural practices used, and yields obtained are about the same as on

Elfrida silty clay loam. Ground water occurs at about the same depth, so pumping costs are reasonable.

Elfrida sandy clay loam (0–0.5% slopes) (Ec).—This soil occurs in all three districts of the surveyed area, but the greater part is in the Whitewater Division in close association with the silty clay loam and clay loam. It is found as smooth areas on the lower reaches of the alluvial fans except in the Willcox Division, where it is on smooth areas of the delta plain and in a few scattered basins.

The 15-inch surface layer consists of brown to pale-brown, coarse granular sandy clay loam. A thin platy crust of sandy loam usually occurs at the immediate surface. Normally the surface soil is noncalcareous, but it contains some free lime in a few places where flooding has occurred. The 15- to 24-inch upper subsoil is brown clay loam to heavy silty clay loam with abundant white lime spots and hard irregular blocky aggregates. From 24 to 36 inches is pale-brown to light-gray clay loam with a greater number of segregated lime spots. The substratum is light-gray, massive, gritty clay loam or loam that contains many segregated spots and streaks of lime carbonate.

In places the surface texture is heavy sandy clay loam on the lower slopes and sandy loam or loam on the more elevated areas. Many lower areas also have a darker surface soil, especially in a few basins in the northeastern part of the Willcox Division and in most places in the Kansas District.

Flooding by drainage water is not uncommon, but no appreciable erosion has developed. Some low wind-blown hummocks have formed around the mesquite vegetation, especially in overgrazed areas. The moisture-holding capacity is high, internal water movement is medium, and drainage below the subsoil is adequate. Ground water occurs at relatively shallow depths in most places. Salts have accumulated in toxic quantities in a small area south of Elfrida.

Use and management.—The carrying capacity is fair to good. The native vegetation is principally mesquite, but bunches of tobosa and occasional thin stands of grama grass are common in some areas. Acacia and fourwing saltbush may occur, and burrograss grows in places adjacent to barren spots.

A small part of this soil is cultivated, chiefly to alfalfa, cotton, hegari, beans, and corn.

Though this soil is not so deficient in organic matter and nitrogen as many soils of the area, improvement can be obtained by planting alfalfa or other legumes in the rotation and by using barnyard and green manures.

Elfrida-Gothard loams (0–0.5% slopes) (Eb).—This complex is comparatively extensive, but only in the Whitewater Division. It is predominantly salty Elfrida loam but there are numerous slick barren spots that are alkaline Gothard loam. On the higher areas of the alluvial-fan slopes probably 75 percent or more of the complex consists of Elfrida loam, but the slick areas of Gothard loam increase in number and size with the downward slope and predominate in the comparatively level areas. The profile of the Gothard loam, except for surface texture, is similar to that for the other Gothard soils described elsewhere in this report. That of the Elfrida loam, except

for surface texture, is the same as that described for the other Elfrida soils.

Surface drainage is very slow on the slick barren areas of the Gothard loam. Water stands on these for extended periods following rains. The salt concentration in these soils varies considerably from place to place and within short distances. The average concentration is slight on the upper slopes but it increases with the distance downward and becomes moderate and strong on the low level areas. Some wind erosion has occurred on barren areas and where overgrazing has reduced the stand of grasses. Wind action has concentrated sandy materials as low hummocks around the mesquite bushes.

Use and management.—The native vegetation—mesquite with some alkali sacaton and tobosa—provides fair all-year grazing.

Some areas of this complex are usually not difficult to reclaim, particularly the higher lying areas where Elfrida loam predominates. The barren slick areas of Gothard loam reclaim very slowly; they need applications of gypsum to make them pervious and to improve their tilth. In places where sandy soils are conveniently close to areas of this complex, the immediate surface of the Gothard loam areas may be improved by spreading the sandy soil over it when leveling land for irrigation. This practice together with incorporation of abundant quantities of organic manures, crop residues, green cover crops, and application of gypsum, should help reclaim the barren slick spots.

FORREST SERIES

The Forrest soils are found most extensively on the western side of the Whitewater Division, but a few small areas are in the western part of the Willcox Division. They occur low on the alluvial fans, most of them in the path of runoff from an extensive drainage area. As a result, sheet erosion and gullying are severe in places. Eroded materials are frequently redeposited as alluvium but may collect as wind-blown hummocks up to 4 feet high around the mesquite bushes.

The parent materials are of mixed origin. They were derived mainly from sandstone and quartzite, but to some extent from shale, limestone, granite, and rhyolite. The parent materials are deposited in a somewhat complex manner. Sometimes they are superimposed on earlier soils, and in places those earlier soils form a considerable part of the present soil section. Some of the materials are reddish, but reddish brown predominates because of the repeated flooding and the slow internal drainage. In many places most of the present surface soil consists of redeposits of fresh materials laid down over soils with truncated profiles. Occasionally these fresh deposits carry lime.

The variable surface soil is dominantly reddish brown or brown and contains 0.7 to 0.8 percent organic matter. Typically, the upper subsoil is reddish brown and the lower subsoil is less reddish and is veined or spotted with accumulated lime and in some places with faint reddish-gray flecks.

Because of erosion, some areas are unsuited to cultivation. Leveling the land and building dikes to divert storm waters would be expensive. Ground water probably occurs at depths that favor pumping for irrigation.

Forrest clay loam (0–0.5% slopes) (FB).—Most of this clay loam occurs west of Whitewater Draw near the southern end of the White-

water Division. Small areas are in the Willcox Division. The soil occupies the lower nearly level part of an alluvial fan where comparatively little erosion has occurred.

The 4- to 10-inch surface soil is noncalcareous brown to reddish-brown clay loam of weak coarse granular to medium fine blocky structure. Where the grass cover is more dense, the surface soil is slightly darker. In some places the surface soil is slightly calcareous. The upper 24 inches of subsoil is reddish-brown silty clay loam or silty clay; it is weakly prismatic to strongly blocky and very hard when dry. From 24 inches down to 36 inches is mildly to moderately calcareous pinkish-gray, light-gray, or pale-brown silty clay loam or silty clay. This layer is massive and hard to very hard when dry. Below this is a light-gray or pinkish-gray more friable silty clay loam in which lime segregation increases rapidly as veins, spots, and other patterns.

Included with this soil are small areas that are calcareous very near to or at the surface because of flooding.

This soil supports a scattered stand of mesquite and acacia, and it is almost continuously covered by sacaton where floodwaters have not been diverted. Runoff apparently spreads out well over the surface and gives rise to a good grass cover. The erosion common to the other soils of this series therefore has not developed. Underdrainage is adequate, but internal movement of water is medium to slow. The soil is reasonably free of salts, but a slight concentration occurs in places. Ground water can be reached at relatively shallow depths.

Use and management.—This soil is used largely for grazing, and the sacaton grass is considered good pasturage. Only a small acreage is farmed, but the soil should be moderately well suited to small grains, hegari, and possibly vegetables. Since this soil is relatively free of the erosion that occurs on the other types, it could be put under cultivation more economically.

Forrest sandy clay loam (0–1% slopes) (FD).—This soil, the most extensive of the series, occurs on very gently sloping alluvial fans, mainly along the southwestern margin of the Whitewater Division (pl. 4, *A*).

The 4- to 12-inch surface layer is reddish-brown or brown sandy clay loam that breaks to hard medium-granular aggregates. The upper few inches are usually slightly vesicular and have a grayish or mottled appearance. Typically, they are leached, but slightly calcareous areas are common because of overwash sediment. The succeeding 12-inch layer—a noncalcareous reddish-brown heavy clay loam is faintly prismatic or strongly medium blocky, hard to very hard, and calcareous in the lower part. Pale-brown to somewhat pinkish-gray strongly calcareous hard silty clay or silty clay loam is at depths of 24 to 40 inches. Below this is pinkish-gray or light-gray silty clay or silty clay loam veined with lime. The veining increases to masses of segregated lime at depths of 48 to 60 inches or more. The depth of the surface soil varies with the extent of erosion or deposition.

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This soil is frequently flooded by drainage waters arising outside the area, and sheet erosion and gullying occur. Internal movement of water is medium to slow, but underdrainage is adequate.

Use and management.—Mesquite and occasional clumps of sacaton grass furnish grazing of good carrying capacity. Farming has been tried on smoother areas, but much of the acreage has been abandoned. Leveling would be necessary for cultivation, and the cost might prove prohibitive under present economic conditions. Though adequate data on suitable crops and yields are limited, it is believed that satisfactory yields of most crops might be obtained by proper management after the soils had been leveled and prepared for irrigation.

Forrest sandy clay loam, hummocky (0.5–1% slopes) (FE).—Windblown hummocks or dunes (2 to 6 feet high) have accumulated around mesquite bushes and trees on one-fourth to one-third of this soil. The dunes distinguish it from Forrest sandy clay loam. The reddish-brown wind-blown material varies from fine sandy loam to clay loam. The surface soil in areas between the dunes is highly variable. It may be a Forrest sandy clay loam surface soil or a wind-blown deposit several inches thick. This soil occurs largely in one continuous area on the western margin of the Whitewater Division.

Use and management.—Because of the hummocks and the consequent high cost of leveling, this soil has an extremely limited value for any farm use other than grazing. The carrying capacity is fair. Isolated clumps of Indian ricegrass and sacaton grow on some of the sandy hummocks. Conservation measures could be used to increase the plant cover and thereby reduce erosion and improve carrying capacity.

Forrest clay (0–0.5% slopes) (FA).—This soil is similar to Forrest clay loam in profile characteristics. It differs in texture of the surface soil and upper subsoil, which is a moderately coarse granular to fine blocky clay for both layers. The clay is noncalcareous, moderately low in organic matter, and low in phosphate. This soil is found at the lower margins of coarser textured soils of the Forrest series. The surface relief is smooth to slightly undulating. Slight sheet and gully erosion occurs.

Use and management.—Forrest clay is used for grazing. Occasional mesquite trees or brush and some sacaton grass form the dominant vegetation. Much of the soil is barren. Because of its fine texture, this soil would be very difficult to cultivate and manage under irrigation. Water spreading, controlled grazing, some reseeding, and applications of phosphate fertilizers are recommended.

Forrest gravelly sandy loam (1–2% slopes) (FC).—Areas of this soil occur on the upper, or somewhat steeper, parts of the alluvial fans. They are closely associated with Forrest sandy clay loam in tracts along the western margin of the Willcox Division. The soil resembles the sandy clay loam except it has a gravelly surface soil and also has gravel strata in the subsoil and substratum. The gravel is subangular or angular and dominantly from rhyolite. Floodwaters from higher fans have cut many shallow gullies 12 to 20 inches deep and 20 inches wide.

Use and management.—None of this soil is farmed. The relief is generally unfavorable for irrigation, and the cost of leveling might prove prohibitive. The pumping lift is greater than for extensive areas of soils better suited to irrigation. In an area where all available water should be used on soils well suited to irrigation, such poorly suited soils as this should be used for purposes not requiring irrigation.

Mesquite and snakeweed form the dominant cover, but much of the surface is barren. Hairy squawbush, crucifixion-thorn, annual grasses, and some flowering herbs are prominent in places. The carrying capacity is fair but possibly might be increased by spreading water and controlling grazing.

FRYE SERIES

The Frye soils occur largely in the Willcox Division, but a few small bodies are in the Kansas District. They occur above most of their associates on smooth round low ridges or smooth slightly elevated areas with a general southeast-northwest trend. The soils are on old delta plain deposits that came mainly from granite and related rocks brought in from outside the area. They are permeable above the hardpan, well aerated, and brown or reddish-brown. Surface runoff is slow. Because the surface soil is permeable, water erosion has not developed. Low wind-blown hummocks, however, are numerous around clumps of mesquite, especially on the coarser textured soil.

These soils have reddish-brown noncalcareous surface layers over reddish-brown upper subsoils that are highly colloidal, blocky, or faintly prismatic. A hard, sometimes glazed, indurated hardpan of extremely variable thickness underlies the upper subsoil. The hardpan is usually in layers that alternate with softer materials.

The native vegetation is usually sparse but includes a wide variety of plants. The grasses are largely annuals and some Rothrock grama. Alfileria, Indian-wheat, scattered mesquite, and occasional yucca are common in some areas. Snakeweed is rapidly invading the overgrazed and sandier places. For seasonal grazing and browse, these soils have a fair to good carrying capacity.

Only a small part is farmed. At the time of the survey, however, extensive areas were being prepared for irrigation.

Frye sandy clay loam (0–0.5% slopes) (Fr).—Areas of this soil, which is more extensive than the sandy loam, are mapped in the delta plain in the northwestern part of the Willcox Division.

The upper 3 inches consist of noncalcareous, reddish-brown, vesicular, platy sandy clay loam and sandy loam. The rest of the surface soil, extending to a depth of 12 or 18 inches is noncalcareous reddish-brown sandy clay loam that breaks into friable medium to fine granules. The subsoil, which begins at a depth of 18 inches and continues to a depth of 30, is slightly darker reddish-brown silty clay with moderately to strongly medium blocky to faintly prismatic structure. It is flecked with lime in the lower part, and considerable gritty material or angular coarse sand is scattered throughout. From 30 to 40 inches are pinkish to reddish-yellow or light-gray, thin, hard, wavy plates that are closely packed and very slowly permeable. These are separated by less firmly cemented reddish-brown materials. The platy hardpan appears to be cemented by lime, iron, and silica.

Below 40 inches the plates are more fragmented, widely spaced, and alternate with looser light-brown sandy loam materials.

The lime hardpan is variable and changes frequently from place to place. In some areas, it occurs as thick, dense, hard layers 6 inches to several feet thick and consists of closely packed thin plates spaced with softer intervening material. Where the more rocklike hardpan is near the surface, the lower material may be comparatively soft and permeable; though some soft cementation with lime, iron, and silica usually occurs. In places, this material has the appearance of a buried or fossil soil.

The slightly elevated areas on which this soil occurs are relatively free from flooding. Ground water occurs 50 to 90 feet below the surface.

Use and management.—The native vegetation has a good carrying capacity. It is largely mesquite with a sparse stand of annual grasses and flowering herbs. Snakeweed is rapidly becoming established on some areas.

The cultivated acreage is hardly large enough to indicate the productive capacity of the soil. Yields, however, show that careful and frequent irrigation and good soil management (including frequent rotation with legumes and application of phosphate fertilizers) would maintain a fairly high level of productivity for most crops grown in the area. Alfalfa, hegari, and corn are the principal crops. If fruit trees are to be planted, the hardpan should be blasted.

Frye sandy loam (0–1% slopes) (Fg).—This soil occupies low, smooth, slightly elevated ridges in the Willcox Division and Kansas District.

To a depth of 2½ inches, the surface soil is noncalcareous, reddish-brown, gritty sandy loam that contains numerous angular quartz and feldspar fragments. The rest of the surface soil, extending to about 15 inches, is noncalcareous reddish-brown friable sandy loam. The upper subsoil, which goes down to depths of 22 to 36 inches, is reddish-brown highly colloidal medium blocky or weakly prismatic gritty clay loam or sandy clay loam. It is noncalcareous in the upper part but is flecked with lime carbonate in the lower part. The upper subsoil is underlain abruptly by a yellowish-brown platy hardpan that appears to be cemented by lime, iron, and silica. This hardpan varies in thickness from place to place and occurs in layers that are separated by softer yellowish-brown materials in which the plates, or layers, become more widely spaced with depth and disappear 5 or 6 feet below the surface. Roots spread horizontally over the top of the hardpan layer.

Subsoil variations are similar to those of Frye sandy clay loam, but the plates are generally more fragmented and not so densely massed as in that soil. Only one or two thin layers of hardpan occur in some areas.

Granite and related rocks are the chief parent materials in the Willcox Division, but considerable rhyolite is included in the Kansas District. Underdrainage is good. Internal drainage, though slow, is apparently sufficient for most crops. Ground water occurs at depths of 60 to 100 feet, and electric power for pumping is available.

Use and management.—The native vegetation has a fair carrying

capacity. It is largely a sparse growth of annual grasses and flowering plants, occasional Rothrock grama, and a scattering of mesquite and yucca. Alfileria and Indian-wheat supply some seasonal grazing.

Crops, yields, and recommendations are similar to those for Frye sandy clay loam. The water requirement for crops is probably a little higher, and it is possible that more frequent rotation with legumes may be necessary to maintain productivity.

GOTHARD SERIES

These soils occupy the salty flats throughout the area. They occur in smooth, very gently sloping to nearly level or level places where surface runoff and internal drainage are very slow. Drainage waters stand on the surface for extended periods. Blown-out spots are common where the soil has become highly saline and flocculated.

Typically, these soils have thin noncalcareous light-gray to pale-brown vesicular and platy or medium to fine granular surface soils and light yellowish-brown colloid-stained, white-capped, columnar upper subsoils. The lower subsoils are tough, plastic, light-brown or light brownish-yellow, and highly lime-spotted or splotched; they may contain localized lime masses at the lower limits. The parent material consists of alluvium derived from mixed igneous and limestone rocks.

Though slick barren areas are numerous, ample vegetation covers most of the soil, and grazing is fair. The most common native plants are mesquite, fourwing saltbush, saltbush, and alkali sacaton. There is a scattering of hairy squawbush, crucifixion-thorn, and seepweed. Owing to high salt content, high alkalinity, and poor physical condition little acreage is being reclaimed.

Gothard sandy clay loam (0–0.5% slopes) (GA).—This soil occupies large salty flats or very gentle slopes throughout the surveyed area (pl. 4, *B*).

The 2- to 3-inch surface soil is noncalcareous to mildly calcareous vesicular platy, light-gray to very pale-brown sandy clay loam or loam. This grades into very pale-brown or brown sandy clay loam that is noncalcareous and breaks to hard fine granules (pl. 5). Extending from a depth of 8 inches to 15 inches is mildly calcareous, light-brown to yellowish-brown, vitreous, colloid-stained silty clay loam or silty clay. This layer has a ½- to 1-inch columnar structure that breaks readily into hard granules. The columns are not recognizable in some areas; in their stead are flocculated, loose, colloid-stained, coarse granules. From 15 to 24 inches is similarly colored, strongly calcareous, massive clay loam seamed or splotched with lime. Below this the subsoil is very pale-brown or light yellowish-brown massive loam or clay loam strongly mottled with white lime. The lower subsoil is variable in texture, color, and lime content. The parent materials consist of alluvium derived from mixed materials high in content of granite or related kinds of rock. In places the alkali structure is not so pronounced as above.

This soil usually contains moderate to strong concentrations of salts and is strongly alkaline below 6 to 8 inches. These conditions have been brought about by floodwater and seepage from extensive high-lying lands in the drainage area and by very slow surface and internal drainage. Flat barren playas and slick areas are common. Sheet

erosion is not prevalent because of the general level relief, but the soil yields readily to accelerated erosion where the slope permits. In such situations, gullies are rapidly becoming incised.

Use and management.—The small acreage now being reclaimed indicates that this soil is not considered favorable for cultivated crops. Extensive areas containing moderate to strong concentrations of salts and alkali probably never can be reclaimed economically. Bordering areas, where the salt content is slight, may yield more readily to reclamation but should be tried experimentally before heavy investments are made. The highly dispersed strongly alkaline sodium clay of the subsoil causes the very slow internal drainage. It therefore may be difficult or impossible to leach out or even move toxic salts from the usual feeding zone of most plants. Frequently more adverse properties follow leaching of the neutral salts; and, unless the leaching is accompanied by applications of gypsum and barnyard manure and incorporation of crop residues and green manures, the alkaline sodium clay subsoil may become hopelessly dispersed.

Gothard sandy loam (0–0.5% slopes) (GB).—Except for its surface texture, this soil is very similar to Gothard sandy clay loam and occurs in close association with it in the Willcox Division and Kansas District. It occupies large salty flats adjacent to the broad playas and very gentle smooth slopes near stony buttes and hills.

The upper 3 to 7 inches consist of very pale-brown mildly calcareous platy sandy loam. Beneath this is a thin gray capping over a columnar layer that extends to 10 or 12 inches. The columns are reddish brown, highly colloidal, and ½ to 1 inch in diameter. They fracture easily into hard, angular, coarse granules or fine blocks. Below 12 and continuing to 36 inches is massive, hard, lime-mottled, pale-brown silty clay loam. This layer is strongly calcareous and contains salt crystals. It is underlain by very pale-brown or light brownish-gray, medium to fine-textured material in which there is a pronounced accumulation of irregularly distributed lime carbonate.

Included areas west of Willcox have a more olive-colored subsoil and substratum. Layers in the substratum consist of lake and delta sediments.

Surface runoff and internal drainage are very slow. Large quantities of salts have accumulated, and the soils are strongly alkaline. Floodwaters remain for extended periods on the salty areas, especially the numerous shallow basins and barren slick areas. These floodwaters cause leaching by removing saline salts from the surface or moving them downward in the profile. The salts are strongly concentrated in the subsoil in many places, and the surface soil is alkaline and dispersed.

Floodwaters may cause some sheet erosion and often cut rapidly, but the smooth flat relief usually prevents any appreciable erosion. Where salts accumulate at the surface, soil materials become flocculated and yield readily to wind erosion. Small wind hummocks around the brush vegetation are usually caused by movement of materials from strongly saline areas.

Use and management.—This soil is as difficult to reclaim as the sandy clay loam, and similar reclamation methods would be required.

HOOKER SERIES

The soils of the Hooker series have a wide distribution. They have developed from dark soil materials of mixed origin. These materials were carried into the area largely from higher grasslands and deposited as alluvium, mainly in the flood plain of Hookers Draw and on fan slopes near Whitewater Draw where definite channels are lacking. The soil profiles depend largely upon the character of the stratified materials laid down. These soils have pale-brown, grayish-brown, or brown, fine-textured surface soils over a pale-brown, fine-textured subsoil that may be mildly calcareous or without free lime. Areas occur in basins and smooth flats and are flooded during torrential rains. They usually support dense stands of grass and scattered mesquite trees and bushes, but barren spots are not uncommon.

Hooker clay loam (0–0.5% slopes) (HA).—The clay loam is the most extensive of the Hooker soils. A large part occurs as an almost continuous body in the lower basin of Hookers Draw, smaller bodies are widely scattered in the upper drainage of Whitewater Draw, and a few small areas are found in the Kansas District.

The 9-inch surface soil is pale-brown, grayish-brown, or brown noncalcareous clay loam; it is almost black when moist. It has weak fine to medium granular structure and is hard when dry but friable when moist. In many places there is a thin surface layer, platy and vesicular and commonly grayer than the material below, that contains about 1 percent organic matter. Lighter grayish brown or pale-brown clay loam occurs between 9 and 30 inches. The aggregates crumble more readily than in the surface soil. The materials below this appear as thickly banded clayey layers interstratified with thin layers of coarser texture. The color is slightly lighter, the materials are more friable, and lime is absent in places, although a slight concentration at this depth is not uncommon. Occasionally limy floodwaters have added lime to the surface soil. Soil of the areas located in the upper 2 miles of Hookers Draw is comparatively dark, friable in the subsoil, and generally noncalcareous to 5 feet or more.

This soil occupies smooth flats and drainage basins and supports luxuriant growths of tobosa and scattered mesquite. When the land has been overgrazed or otherwise denuded, revegetation is usually slow. Apparently this is due to the crusting of the surface soil and to flooding, as the soil is neither salty nor highly alkaline. The water-holding capacity is high.

Use and management.—Approximately 266 acres were under irrigation in 1939, but since that date extensive areas have been cleared for irrigation and are used largely for cotton, small grains, alfalfa, hegari, chili, beans, and vegetables. The rest is used for natural range, on which grazing is exceptionally good. This soil has good potential value for small grains, grain sorghums, and other field and truck crops requiring fine-textured fertile soil. Plowing under crop residues and manure should keep this soil in good tilth and promote higher yields.

Good quality water for domestic and irrigation purposes is found 30 to 60 feet below the surface in most places, and electric power for pumping is usually available. During the rainy season, many low areas in Hookers Draw are subject to flooding and require dikes for protection from floodwater before they can be successfully farmed.

Hooker clay loam, eroded (0–1% slopes) (HB).—The small areas of this soil are found in the Willcox Division. The soil is similar to the uneroded Hooker clay loam, but in some places it is cut by gullies and in others is covered by soil material eroded from adjacent higher lying areas.

Use and management.—Vegetation consists mainly of annual weeds and grasses and some mesquite and bushes. A limited stand of tobosa occurs in places, and barren areas between trees and bushes are common. None of this soil is cultivated. It is of good quality for irrigation, but considerable expense would be required for leveling and for controlling floodwater because of its eroded condition and location.

Hooker sandy loam (0–0.5% slopes) (HC).—This sandy loam occurs principally near Elfrida. It is usually lighter colored throughout than Hooker clay loam, and the clayey subsoil is more frequently interstratified with coarser textured materials. Lime carbonate is absent or is present in small quantities in the deeper subsoil.

The surface, 2 to 6 inches in depth, ranges from heavy sandy loam to loam and sandy clay loam. Areas 1 to 2 miles north and northwest of Elfrida are somewhat variable in surface texture and in degree of development. The upper part of the subsoil is hard to very hard in places, but the material crumbles to fine blocky aggregates that are hard when dry and firm to friable when moist. Areas adjacent to or near the Courtland soils generally have browner surface soils, and in places the 4- to 8-inch surface soil consists of brown friable sandy loam to sandy clay loam.

As this soil occurs largely on smooth alluvial-fan slopes, it does not receive so much runoff as Hooker clay loam and its stand of grass is therefore less dense. Many areas contain scattered mesquite, and some are almost barren. The grazing value is therefore reduced; but except on the barren areas, the soil is usually more permeable and more easily worked than Hooker clay loam. The water-holding capacity is moderate, but infiltration is somewhat slow, especially on the barren areas.

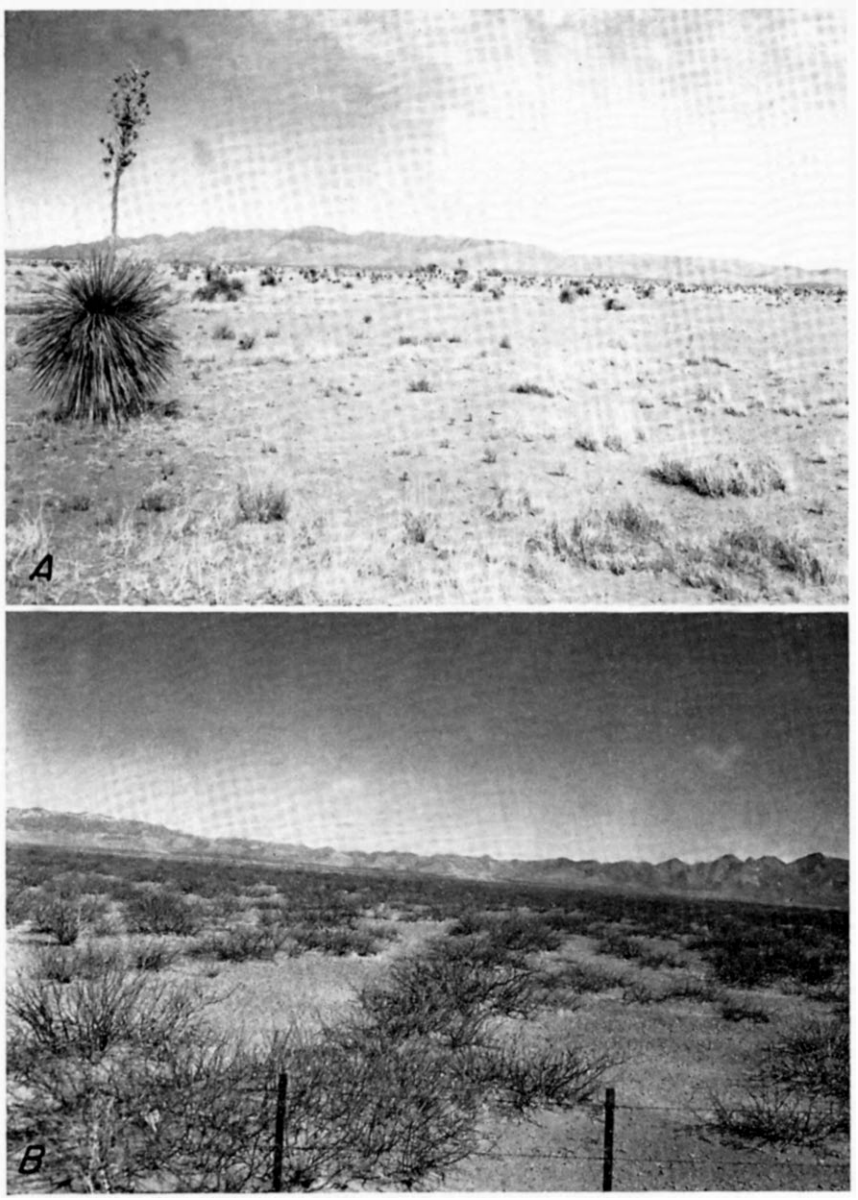
Slight sheet erosion occurs. Fine sandy loam, loam, or silt deposits and sandy hummocks are not uncommon.

Use and management.—Only a small part is farmed. Crops grown are similar to those on the uneroded Hooker clay loam, and yields are about the same. Similar practices are recommended to improve permeability and tilth.

The water lift for irrigation is about 40 to 70 feet, and it should be economically feasible to reclaim and irrigate a large acreage now that electric power is available. Dikes are essential in places to divert floodwaters from farm land.

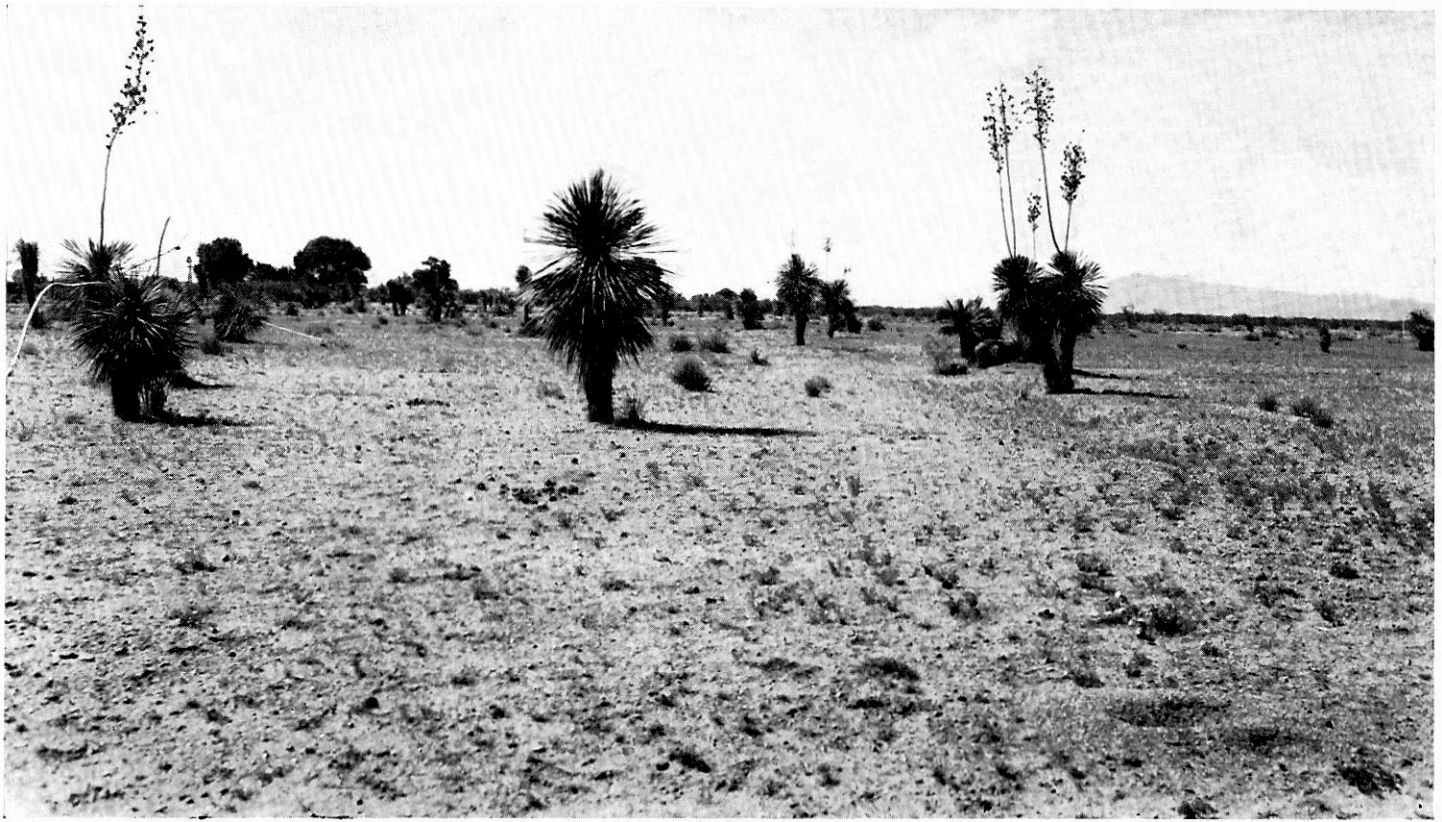
KARRO SERIES

The Karro soils occur on the lower margins of alluvial fans, in flat valley basins, and in playas. The parent rocks are from mixed igneous and limestone formations. The soils have an unusually thick layer of accumulated lime in the subsoil. The lime occurs predominantly as marl, but in places it forms a soft to moderately cemented hardpan. Much of this series occurs in comparatively low areas where seepage



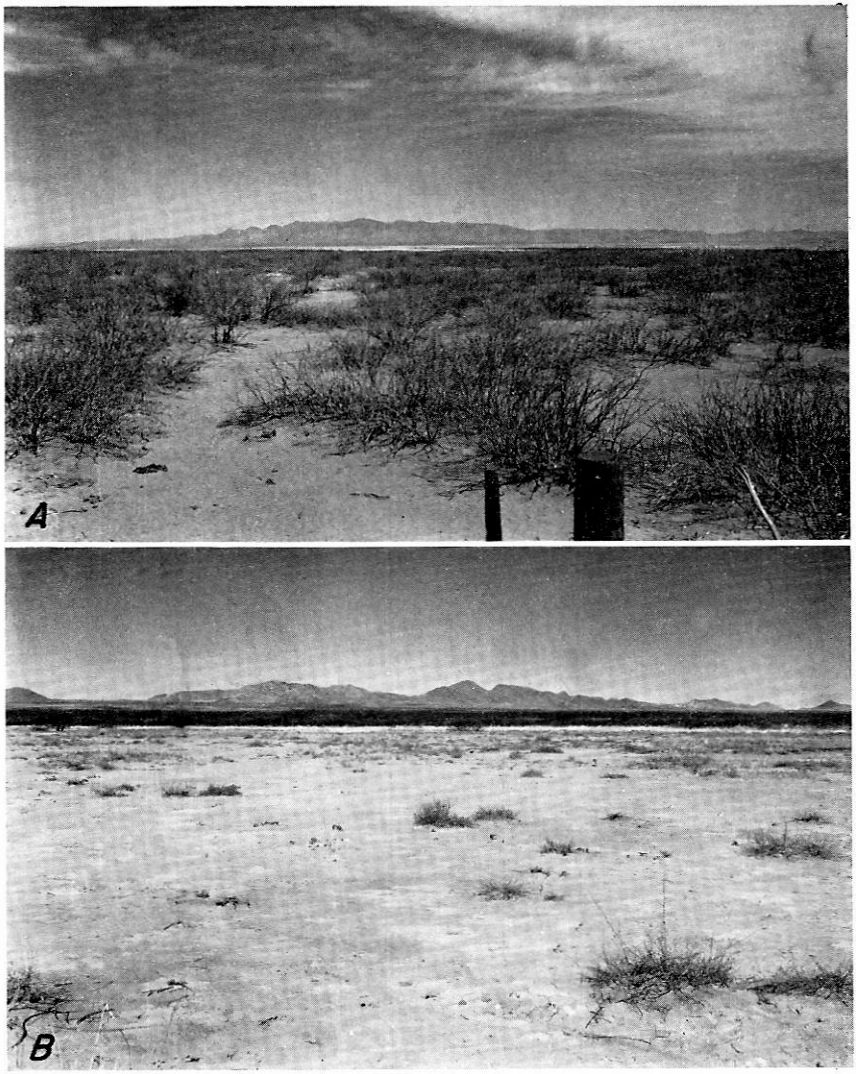
A, Landscape of Briscoe soils: Briscoe loam in foreground; Briscoe sandy loam, nearly level, in background.

B, Mesquite on Continental sandy loam; surface usually barren of vegetation and covered with a thin layer of pebbles.



Cowan loamy coarse sand showing characteristic yucca that thrives on this coarse-textured porous soil.

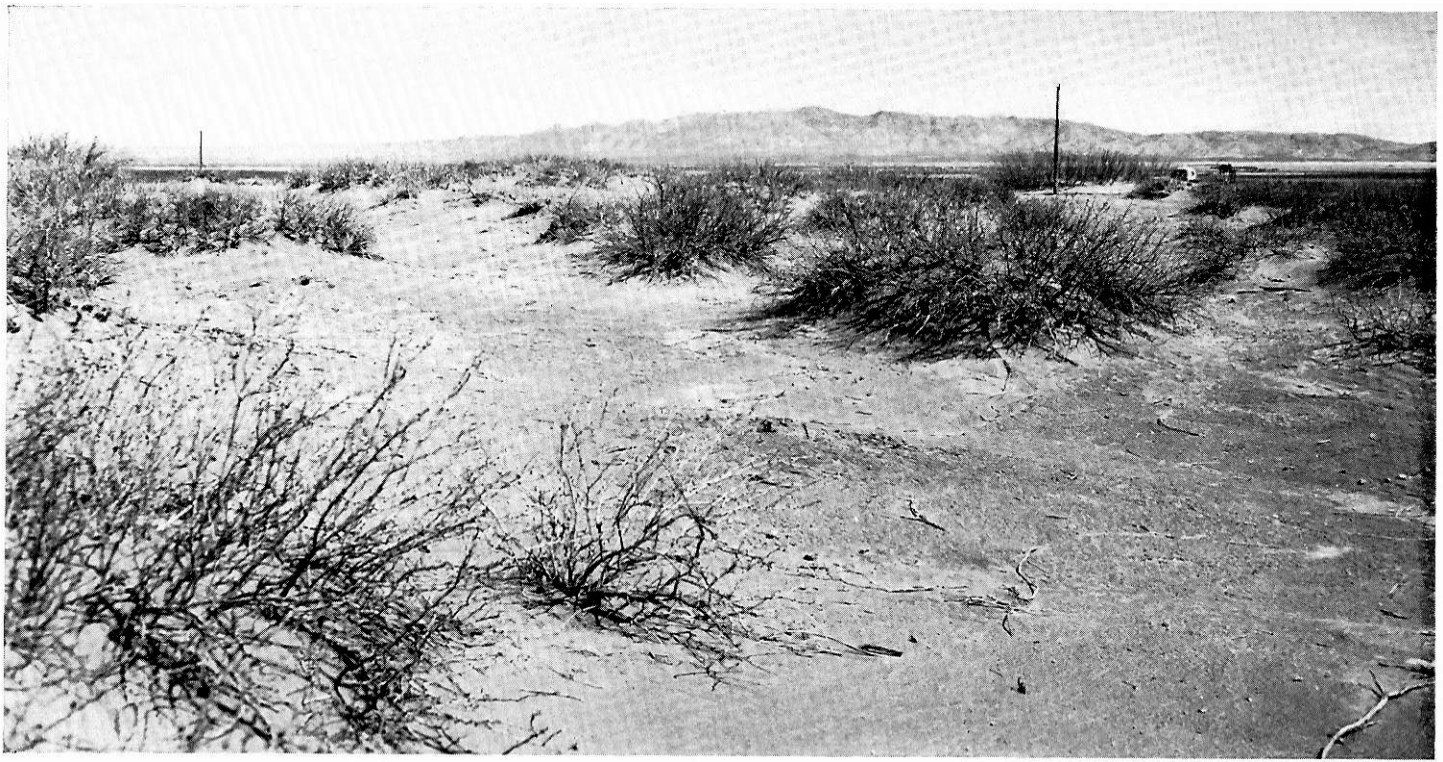
A, Landscape of Elfrida silty clay loam showing tobosa and scattered clumps of mesquite.
B, Profile of Elfrida silty clay loam. Depth to white-flecked zone of lime accumulation is about 20 inches.



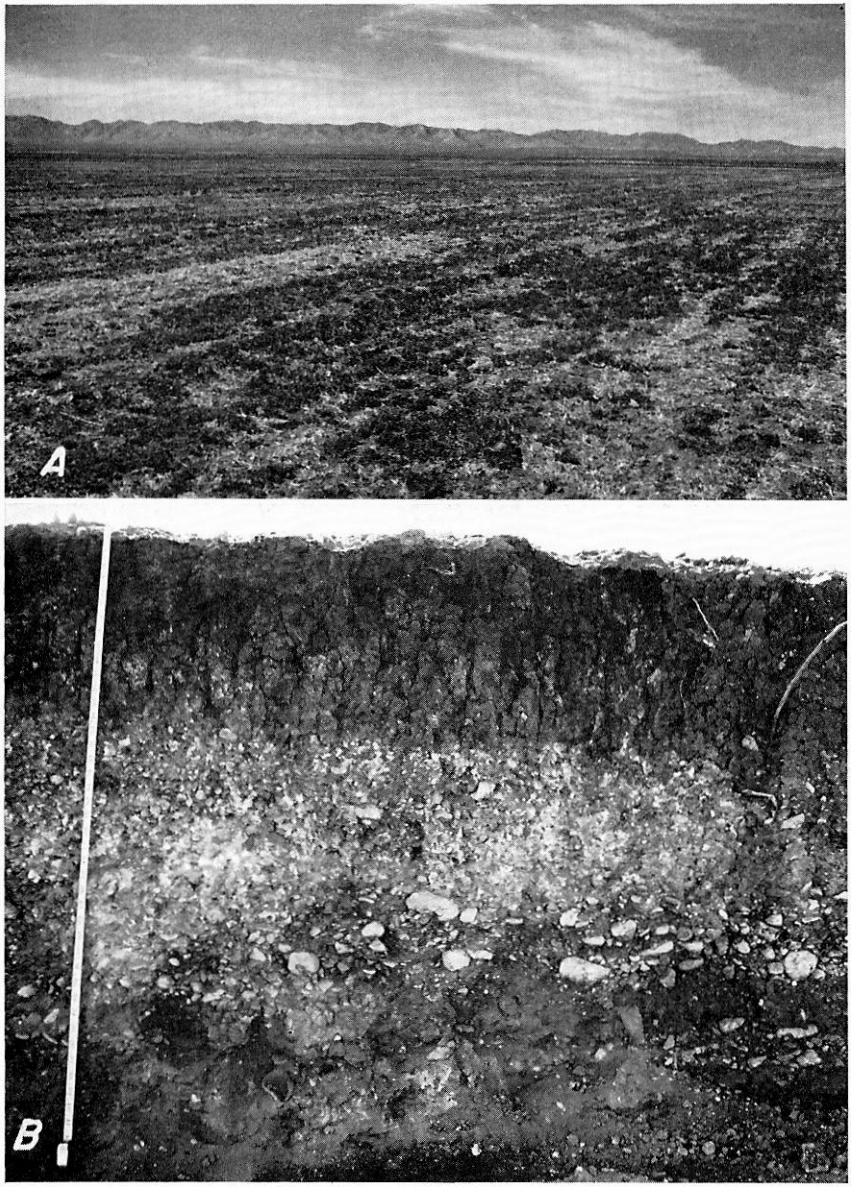
A, Landscape of Forrest sandy clay loam showing characteristic low hummocks of loamy sand that have accumulated around mesquite bushes.

B, Landscape of Gothard sandy clay loam characterized by sparse vegetation and slick and barren spots. Denser vegetation in background is on less alkaline Gothard and Riggs soils; Courtland loamy coarse sand is on the very gently sloping fans dimly visible at left below highlands in far background.

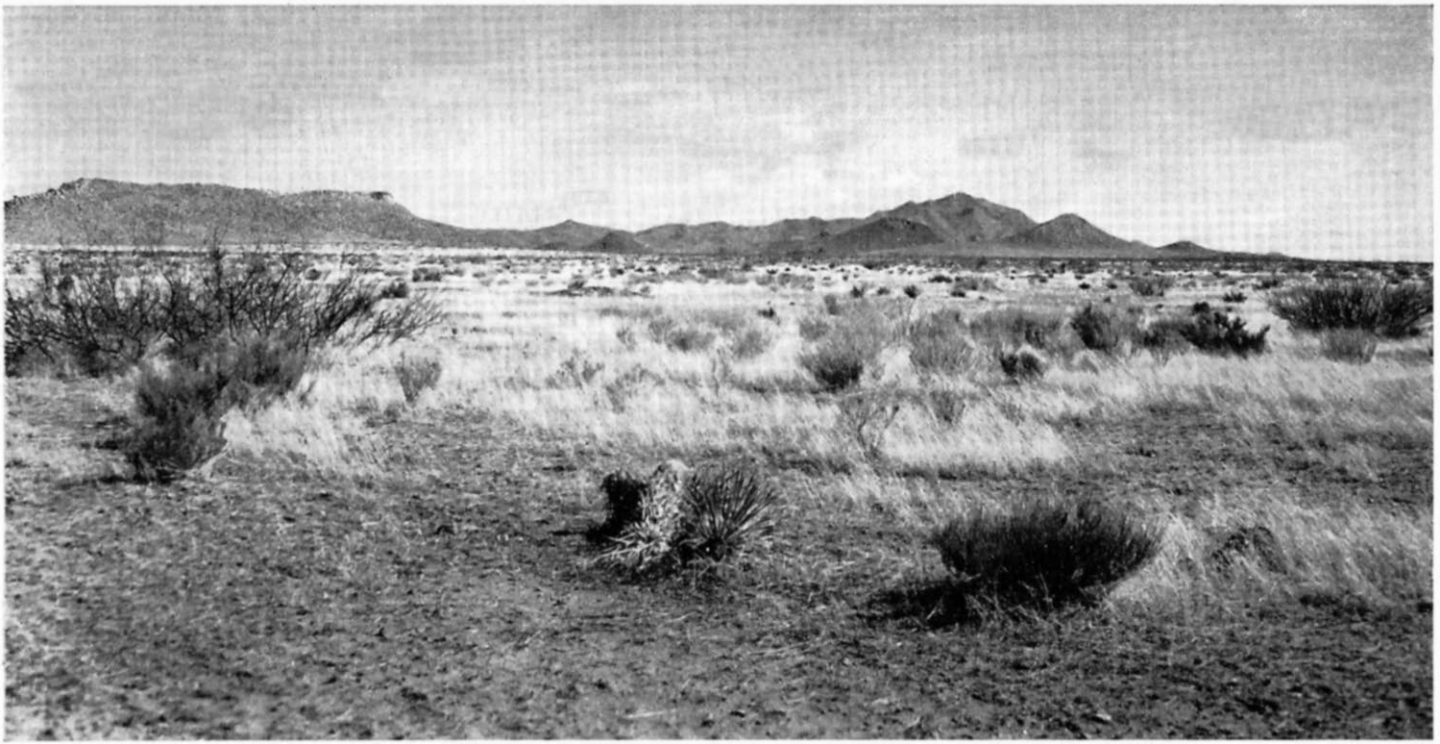
Profile of Gothard sandy clay loam: 0–6 inches is surface soil; 6–11 inches, ashy horizon; 11–18 inches, weak columnar horizon; and 18+ inches, massive material that contains much disseminated carbonate of lime.



Characteristic relief of Kelton loamy sand, hummocky.



A, Irrigated alfalfa field on McNeal sandy loam.
B, Profile of McNeal sandy loam; depth to gravelly calcareous subsoil is about 16 inches, which is somewhat shallower than normal for this soil.



Characteristic landscape of Tubac sandy loam on the upper parts of the very gently sloping alluvial fans; vegetation chiefly grama grasses and scattered mesquite, broomweed, and yucca.

water has approached the surface and caused saline conditions. Extensive areas are moderately or strongly alkaline as well as saline. Such soils are not well suited to irrigation.

Karro sandy loam (0–0.5% slopes) (KD).—This soil is widely distributed as relatively small bodies throughout the three districts of the survey area. The 6-inch surface soil is strongly calcareous, slightly hard, light-gray to pale-brown sandy loam. It has a weak fine to medium granular structure and contains scattered hard angular caliche fragments. Pale-brown or light gray sandy loam to light clay loam begins at a depth of 6 inches and continues to 16 inches. It is weak medium to fine granular in structure, is hard in places, and contains a few caliche fragments. It ends abruptly on a light-gray to white marly layer, capped in places by a fragmental hardpan. This hardpan consists of weakly cemented lime nodules in many areas. The depth to the nodular lime zone ranges from 12 to 48 inches, but everywhere the subsoil is strongly calcareous and moderately permeable to moisture. Iron staining and olive shades are common in this marly subsoil.

Much of this soil, especially in the Willcox Division, is highly charged with salts. In such areas the subsoil may contain mottled light-gray and olive hard layers of clay between comparatively hard layers of lime, or there may be massive concentrations of this clay in the lower subsoil. Elsewhere internal drainage is usually retarded, and the salt content is relatively high but not concentrated in toxic quantities.

Though this soil occurs in basinlike areas, it is usually on the slightly elevated parts relatively free from flooding. Surface drainage is slow. Considerable sheet erosion has occurred in places. Wind erosion, however, is generally more active, and in some areas the white marly subsoil is exposed and hummocks are numerous.

Use and management.—The native vegetation, principally mesquite, fourwing saltbush, fluffgrass, sacaton, burrograss, and flowering annuals, provides fair grazing.

Owing to the small acreage in cultivation, little definite information is available on the agricultural possibilities of this soil. Crop yields are said to decline rapidly, and often crops do not mature satisfactorily. Fruit trees are subject to chlorosis. These unfavorable conditions probably result from the limy character of the soil, high alkalinity, and salts. Applying soluble phosphate and barnyard manure and plowing under crop residues and green manure should prove beneficial.

Karro sandy loam, hummocky (0–0.5% slopes) (KE).—This inextensive soil occupies a few small bodies in the Willcox Division and Kansas District. More severe wind erosion differentiates it from Karro sandy loam. Numerous hummocks of sand or loamy sand, ranging up to 36 inches high, have accumulated around clumps of mesquite. The vegetative cover is similar to that on Karro sandy loam but is less dense. The carrying capacity is low. Barren places and areas where the white marly subsoil is exposed are extensive. Because of the cost of leveling and the many severely eroded areas, this soil is not well suited to irrigation farming.

Karro loam (0–0.5% slopes) (KA).—The loam is mapped throughout the surveyed area. It usually occupies somewhat elevated positions that are slightly lower than those occupied by the associated Karro sandy loam.

The 9-inch surface soil is friable light-gray to pale-brown strongly calcareous loam. It contains numerous lime nodules and caliche fragments. From 9 to 20 inches is light-gray, marly, hard, massive light clay loam to silty clay loam. In some areas, especially where the soil is salty, this layer contains much weakly prismatic clay. It grades into weakly cemented nodular caliche underlain by alternating layers of light-gray, limy, gritty, blocky clay loam and fragmental hardpan. At the lower limits, especially in saline areas, the clay layers have an olive cast or olive mottling.

The depth of the surface soil and the character and density of the limy layer in the subsoil are variable. The subsoil is usually more clayey in saline areas than elsewhere. The parent rock materials are largely from noncalcareous mixed igneous formations, but geologic erosion, deposition, and soil formation have caused them to become highly saturated with lime.

Surface drainage, especially in the salty basin areas, is slow. This slow internal drainage is sufficient, except on the lower lying salty areas where water ponds for several days after rain. A considerable acreage in the Willcox Division is highly charged with salt and is strongly alkaline. Elsewhere salt concentration is high in places.

Sheet erosion occurs in some areas, but the most significant removal is by wind. Surface materials are readily removed and blown into numerous small hummocks around bushes.

Use and management.—The vegetation is variable. Some areas support only fluffgrass, burrograss, and annual gramas; others, usually on the more nearly level places that contain some salt, support a scattered stand of mesquite, chamiza, saltbush, and alkali sacaton and provide fair grazing.

Yields obtained on the small acreage farmed indicate that this soil is not especially favorable for crops.

Karro loamy sand (0–1% slopes) (KB).—Like the other Karro soils, the loamy sand has a highly calcareous profile underlain by soft caliche. It differs, however, in having a less calcareous surface soil and a darker surface color, particularly when moist. It is weakly calcareous to 6 or 12 inches but is noncalcareous in a few places. It differs from the closely associated Karro hummocky sandy loam in having fewer and smaller wind-blown hummocks and a distinctly darker surface soil. It is very susceptible to wind erosion. Most of the acreage occurs in an area in the central-western part of the Kansas District. Except for grazing, it has a low value for farming because of its very porous and loose surface soil.

Karro loamy sand, hummocky (0–1% slopes) (KC).—Most of this hummocky soil occurs in a continuous body along the western border of the Kansas District. The subsoil resembles other Karro subsoils, but the surface soil is very friable or loose and is blown into hummocks and irregularly shaped dunes. Blowout spots of exposed hardpan are numerous among hummocks and dunes that rise to 6 feet or more. Much of this sand was probably blown in from the west.

The sandy materials are from mixed igneous rocks, largely granite or related stone. It is probable that the sand accumulated in a lake or on its shoreline when water occupied the adjacent playa. Subsequently the sand was blown to its present position.

Although the sands migrate constantly and cut or bury vegetation, mesquite and yucca retain a foothold under the more adverse conditions. Occasional annual grasses, fluffgrass, and flowering annuals are common on smoother bordering areas. This soil is of low value for grazing. The loose shifting sand and the hummocky or dune relief are unfavorable for farming.

KELTON SERIES

Kelton loamy sand and its hummocky phase occur in the Whitewater Division west of Whitewater Draw on large gently sloping ridges that rise above the surrounding country. Apparently the ridges have been built up by wind action over a long period. The surface configuration is broken by numerous large hummocks, 2 to 6 feet or more high, that have accumulated around clumps of mesquite. The sandy parent materials are from mixed sources, including sandstone, quartzite, granite, or related rocks.

Mesquite and catclaw are almost the only vegetation that consistently withstands the cutting action of the wind and sand. Some Indian ricegrass occurs in places. The partly buried mesquite affords some browse. The cost of leveling the hummocky phase for cultivation would probably be prohibitive, and subsequent methods of stabilizing the soil would probably prove ineffective. Attempts to farm the more nearly level areas have been futile.

Kelton loamy sand (0–1% slopes) (KF).—Sandy hummocks do not occur on this soil, which is located about 5 miles southwest of McNeal in several separate areas. It is associated with Kelton loamy sand, hummocky, and with Forrest soils. Some areas are the partly leveled hummocky soil.

The surface soil, extending to a depth of about 6 inches, is reddish-brown noncalcareous loamy sand or loamy fine sand. It is very slightly firm in place but is comparatively loose when disturbed. It contains about 0.3 percent organic matter. Below the surface soil and continuing to more than 5 feet is reddish-brown to red noncalcareous loose loamy sand or sand.

Use and management.—The soil is not only low in organic matter but also difficult to farm. Because of the very sandy texture, the soil blows freely and would require large quantities of irrigation water. The content of soluble phosphates is very low. Practically all the areas were once prepared either for dry farming or for irrigation and later abandoned. The vegetation consists of occasional small clumps of mesquite that have started growing since the land was abandoned. This soil has little value for agriculture in its present condition. Seeding suitable drought-resistant grasses would provide some grazing and possibly might reduce blowing of the surface soil.

Kelton loamy sand, hummocky (0–1% slopes) (KG).—In the more stabilized areas between the hummocks or dunes, the surface 9 inches consists of noncalcareous reddish-brown slightly hard to loose loamy sand (pl. 6). Below 9 and continuing to about 60 inches,

the material is loose noncalcareous red loamy sand. Below 60 inches is loose incoherent red sand that is mildly calcareous in some places. It is not uncommon to find thin (½ to 6 inches), hard to very hard pinkish-gray layers at variable depths. They appear to be tightly packed loamy sand and possibly represent an old surface that was exposed for a long period. This suggests that periods of temporarily arrested activity have occurred in building up sandy parent materials. The material in the dunes is loose noncalcareous reddish-brown to red loamy fine sand or sand.

MC ALLISTER SERIES

McAllister soils, the most extensive soils with lime hardpan, have been mapped only in the Willcox Division. They occupy relatively smooth and flat areas in the gently sloping valley plains in close association with Frye and Cogswell soils. Periodic flooding is common during rainy periods, but because of the nearly level relief, little erosion has developed. Surface drainage is slow; internal drainage, though slow to very slow, is adequate for most crops. Though these soils are relatively free from toxic concentrations of salts, they may have a slight accumulation where they merge with salty soils of the more nearly level valley basin. When selecting land for cultivation in these positions, it is recommended that the soil map be used as a guide. Ground water usually occurs at 40 to 85 feet.

These soils have developed from materials of mixed origin, predominantly acid igneous rocks. They have a light-brown friable surface soil and a light reddish-brown strongly developed, hard, blocky, sandy clay loam or clay loam subsoil. Under the subsoil lies a dense fragmental lime hardpan of platy character, the plates alternating with softer materials. McAllister soils differ from Cogswell soils mainly in having less organic matter in the surface soil and in having a finer textured more reddish-brown subsoil above the hardpan.

On the smoother relief, the native vegetation is largely tobosa with a scattered stand of mesquite trees and bushes. Elsewhere mesquite, sacaton, burrograss, and snakeweed are common.

McAllister sandy clay loam (0–0.5% slopes) (Mc).—Elongated bodies of this soil are widely scattered throughout the valley plains of the Willcox Division. They have developed from mixed materials, predominantly granite and related rocks. These materials were laid down as very gently sloping smooth or nearly level areas in the old delta plain of the Willcox Division.

The 5-inch surface soil is noncalcareous light-brown weakly platy sandy clay loam or loam. It contains about 0.75 percent organic matter. From 5 to 12 inches is noncalcareous light reddish-brown sandy clay loam of moderate coarse blocky structure that breaks easily to hard, small, blocky fragments that are friable when moist. In places this layer is mildly to moderately calcareous in the lower part. The layer extending from a depth of 12 to 22 inches is reddish-brown clay loam of weak fine to medium prismatic structure. It crushes readily to small blocky aggregates that are hard when dry and firm when moist. It is moderately to strongly calcareous and has many lime flecks and veins. The lower subsoil is pale-brown to very pale-brown highly calcareous massive clay loam that breaks into irregular

aggregates that are hard to very hard when dry and firm when moist. A light-gray weakly to strongly cemented lime hardpan occurs at depths ranging from 30 to 48 inches. It has hard wavy lime plates. The plates are densely massed at the top but become widely spaced between alternating layers of softer, pale-brown gritty clay loam materials. Some exposures made in digging wells show that thick caliche layers continue to undetermined depths and may alternate with materials having the appearance of a fossil or buried soil.

This soil is frequently overflowed during the rainy period, but the slow surface drainage is sufficient to prevent prolonged ponding or waterlogging. The slow internal and underdrainage are generally adequate even under irrigation. Where this soil occurs near the barren playa basin, slight to moderate concentrations of salts may occur. Nevertheless, most of the small barren areas appearing to be slick spots are caused by factors other than salts or alkali. It is possible that the impact of torrential rains may disperse the fine surface sediments in these basins. Then baking by the hot sun forms a glazed surface unfavorable for water penetration and the germination of seed, even though the content of sodium is low.

A few slick spots occur in saline areas and more may develop when saline or saline-alkali areas are being reclaimed. Gypsum and manure aid in correcting slick spots caused by sodium. Detrimental quantities of sodium occur in the fine-textured subsoil of the northeastern part of sec. 15, T. 13 S., R. 24 E. Leveling in that area decreased the thickness of the surface soil in some places and increased it in others. Crops grow where the surface soil is thicker but are retarded where their roots reach into sodium-bearing subsoil. The result is uneven stands.

Use and management.—The native growth of mesquite, snakeweed, sacaton, and burrograss provides good grazing.

Most cultivated areas are used for alfalfa, small grains, hegari, and beans. Under good management and with careful irrigation, fair yields are usually obtained. Bean yields are frequently reduced by blight. For much of this soil, ground water is at depths of 40 to 85 feet. Electric power is available from rural electrification lines, and it is probable that a large acreage will be put under cultivation. Care should be taken to avoid cultivating areas adjoining the salty basin, as in places these contain enough salt or alkali to injure crops.

The lime hardpan varies considerably, or from thick dense hard layers to thin fragmental plates. The difficulty in root and water penetration is dependent on the nature of the hardpan. On the whole, the hardpan does not prevent good yields if careful management and irrigation are practiced. The mineral elements needed for fertility are not known to be deficient under cultivation, and a good level of productivity has been maintained by using manures and crop rotations that include legumes to provide organic matter and nitrogen. Such crops as alfalfa profit by use of soluble phosphate, which is essential because of the moderately shallow feeding zone and the highly calcareous indurated subsoil. Gypsum, manures, green manures, and crop residues improve the permeability and tilth of slick barren spots.

McAllister sandy loam (0–0.5% slopes) (Md).—Areas of this inextensive soil are closely associated with other McAllister soils north-

west of Willcox. It differs from the sandy clay loam principally in having a coarser textured surface soil.

The surface soil ranges from 3 to 8 inches deep. It is weakly platy and slightly hard in the upper part but crumbles to medium to fine granules. To some extent the sandy character carries into the subsoil. As a result, the surface soil and upper subsoil are slightly more friable and permeable than those of finer textured McAllister sandy clay loam.

This sandy soil occupies slightly elevated places and is relatively free from flooding. Surface runoff is slower and internal drainage slightly more rapid than for McAllister sandy clay loam. Ground water occurs at about the same depth as under the other McAllister soils.

Use and management.—The native vegetation of scattered mesquite, snakeweed, sacaton, and burrograss has a good carrying capacity. The crops grown and the yields obtained are similar to those on McAllister sandy clay loam, but this soil is probably more suitable for alfalfa, hegari, beans, and fruits.

McAllister loamy sand (0–0.5% slopes) (MA).—This soil occurs in many widely separated small bodies in the Willcox Division in association with other McAllister soils and with Cogswell and Frye soils. It is much like McAllister sandy loam but has a coarser texture in the upper 7 to 15 inches. Wind erosion is moderate and forms many sand hummocks around mesquite bushes. The hummocks, however, are dominantly less than 12 inches high. Sheet erosion is negligible except in some overgrazed areas.

Use and management.—This soil is used for grazing. If it is cultivated, care will be needed to prevent blowing. Blowing, however, would be less severe than on many other soils of loamy sand texture, as the sand particles of this soil are dominantly from granite or somewhat similar rocks that yield angular rather than rounded sand grains. Except for control of blowing, the recommendations regarding use and management for the other McAllister soils apply to this one.

McAllister loamy sand, hummocky (0–1% slopes) (MB).—This phase occurs about 8 miles north of Willcox. It is like McAllister loamy sand, but wind erosion has been more severe. Numerous sand hummocks blown up around mesquite and fourwing saltbush reach a maximum of more than 36 inches in height and average 24.

Use and management.—The soil is used for grazing, but the carrying capacity is low. As it would be expensive to level the soil for irrigation farming and difficult to control erosion, grazing is probably its best use. Controlled grazing and seeding of suitable grasses are recommended. Vegetation at present includes mesquite, fourwing saltbush, yucca, Indian ricegrass, and some annual grasses and weeds.

MCNEAL SERIES

The soil of the McNeal series occurs only in the Whitewater Division near McNeal. It occupies fairly smooth broad ridges that descend well into the valley plain, and it is relatively free from the flooding that often takes place on such associated lower lying soils as the Elfrida. It differs from the Elfrida in surface color and in content of gravel in the substratum. Characteristically it has developed

from more gravelly alluvium and has more rapid internal drainage and a slightly lower moisture-holding capacity than Elfrida soils. Sheet erosion is slight, and gullies are infrequent.

The reddish-brown friable surface soil overlies an upper subsoil that is contrastingly more reddish, colloidal, and blocky or weakly prismatic. This reddish upper subsoil gives way rapidly to a gravelly lower subsoil of lighter brown color. Concentrations of lime occur in spotted and streaked patterns in the subsoil. The parent rocks are of mixed origin but are predominantly from rhyolite and quartzite.

The native vegetation consists largely of a scattered stand of mesquite, yucca, and annual and perennial grama grasses and a dense stand of tobosa in the more nearly level areas. The carrying capacity varies from place to place.

McNeal sandy loam (0–0.5% slopes) (ME).—The 3- to 10-inch surface soil is noncalcareous, brown or slightly reddish-brown, friable, weakly fine to medium granular sandy loam or gritty loam containing occasional pebbles (pl. 7, *A* and *B*). This layer contains about 0.65 percent organic matter. Beneath this layer and continuing to about 18 inches is pronounced reddish-brown clay loam or weakly prismatic sandy clay loam. This breaks to coarse and medium blocky material that is hard when dry. Lime spots appear in the lower part. This layer offers some resistance to roots, as many of them follow fracture planes. From 18 down to 36 inches is brown, yellowish-red, or pale-brown clay loam of more massive structure. It is abundantly spotted with lime and usually contains many pebbles. Below this layer are alternating layers of rounded pebbles and pale-brown or light-brown coarse sand that is somewhat grayish in the lower part because of accumulated lime.

The gravel content varies considerably from place to place. The larger concentrations appear on the more pronounced ridges or elevated situations. The depth to the gravelly subsoil is slightly greater in most areas south and west of McNeal. Owing to the clay in the upper subsoil, however, the moisture-holding capacity is probably sufficient for crops grown under careful irrigation practices. Most areas are sufficiently smooth for satisfactory water distribution, but depth to ground water may limit irrigation on the higher situations. Sheet and gully erosion are not severe, but the surface soil is eroding from a number of overgrazed areas.

Use and management.—All of this soil is used for grazing, and the carrying capacity is fair. Most areas would produce satisfactory yields of nearly all suitable crops if soluble phosphates were applied, the organic matter and nitrogen deficiencies were corrected by using fertilizer or legumes in the rotation, and crop residues and manure were plowed under.

MIMBRES SERIES

The Mimbres soils are widely distributed in the Willcox Division and Kansas District. They characteristically occur as elongated narrow bodies, both on the alluvial fans and in the more nearly level basins of the valley plain. The parent materials came from rhyolite and other igneous rocks.

The brown surface soils and upper subsoils become lighter colored in the lower more definitely stratified subsoil and substratum. Clay

accumulation is discernible in the subsoil, and lime usually occurs in a fine netted or mycelial pattern. The soils of this series most nearly resemble Elfrida soils but differ from them in having a greater depth to the lime layer and less accumulated lime.

Tobosa grass and a scattering of mesquite are dominant in the basins and more nearly level areas, but grama grass and various flowering herbs and annual grasses grow between the mesquite trees or bushes at a slightly higher elevation. These soils occur mostly in sections used principally for grazing, but some small areas are cultivated and irrigated. Water is usually available within economical pumping depth.

Mimbres clay loam (0–0.5% slopes) (MF).—This soil, the most extensive of the Mimbres series, is widely distributed in the tobosa flats and basins throughout the Kansas District and Willcox Division. At the surface is 1½ inches of light grayish-brown clay loam of platy vesicular structure. This layer is underlain to a depth of about 10 inches by brown or pale-brown, noncalcareous clay loam, generally friable but somewhat plastic when wet. This layer has a moderate medium to fine granular structure and is hard when dry. The organic-matter content of the surface layers is about 1.6 percent. The upper subsoil is moderate blocky to weakly prismatic brown silty clay loam or silty clay; it is faintly veined or netted with lime in the lower part. This lime pattern grades at 36 inches into a paler brown, hard, massive silty clay loam. Below 48 inches is friable massive pinkish-gray loam or silt loam. Lime carbonate is uniformly disseminated.

In some areas in the Kansas District, the lower subsoil rests upon a former surface of an earlier soil. No visible lime is apparent to depths of 3 feet or more in some areas. Occasional tracts have been overgrazed and have been further denuded by sheet erosion or covered with materials deposited during floods. In its low-lying position, this soil is subject to occasional flooding during the rainy season. Internal drainage is medium.

Use and management.—The acreage under cultivation is being expanded rapidly. Favorable yields of grain, alfalfa, and hegari are reported. The relatively high organic-matter content and friable moderately permeable nature of this soil suggest that small grains, hegari, and other acclimated crops can be grown successfully. The soil is covered by an almost continuous growth of tobosa grass and a scattering of mesquite. The carrying capacity is fair except in overgrazed areas. Water-bearing strata occur at 50 to 70 feet in most areas, and some wells in the Kansas District tap artesian water that rises to the surface. Much of the cultivated acreage is given flood protection to divert storm waters.

Mimbres loam (0–0.5% slopes) (MG).—The loam is associated with Mimbres clay loam and occupies somewhat similar smooth and level positions, but it is higher on the alluvial fans or adjacent to sandier soils.

In characteristics other than texture of the surface soil, this soil is much like Mimbres clay loam. The two soils have similar variations, but those of this loam are wider. Its surface texture ranges from sandy loam to clay loam. In places the top 2 to 4 inches consist of a recent coarse-textured deposit overlying a much finer material. A few areas

have relatively large quantities of gravel in the surface soil and are shown on the map by symbol. Sheet erosion is marked, and small wind-formed hummocks are common around brush.

Use and management.—Most of this soil is used for grazing, but some is under irrigation. Barren areas occur, though generally there is a good cover of tobosa and sacaton and a scattering of mesquite, crucifixion-thorn, and hairy squawbush. The carrying capacity is about the same or slightly less than that of Mimbres clay loam. Little information concerning crops or yields is available; but this soil has characteristics resembling those of Elfrida sandy clay loam, and it seems that similar crops might be grown and similar yields obtained.

The water lift and artesian possibilities are about the same as for Mimbres clay loam. Dikes will be needed to divert floodwaters from areas reclaimed for irrigation farming.

RIGGS SERIES

The Riggs soils occur only in the lower part of the valley plain along Whitewater Draw. The valley trough is nearly level, and the gradient is very gently southward. The channel of Whitewater Draw ranges from a few inches to about 20 feet deep, and in places numerous vertical-walled tributaries give rise to somewhat irregularly shaped eroded areas. The tributary channels extend back in a dendritic pattern through most of the area covered by these soils. Areas between the gullies are subject to heavy sheet erosion, especially near the steep-walled gullies. Internal drainage is very slow, owing to the fine texture and dispersed sodium clay.

These soils have developed from fine-textured stratified materials of mixed origin, to which dark-colored sediments eroded from higher areas have contributed. The profile characteristics are variable from place to place, especially from north to south. In the more typical locations, the soils have a thick, salty, granular, grayish-brown surface layer over a gray subsoil in which there are salt crystals and thin white mycelial threads of lime. The substratum is mottled light-gray clay, massive, spotted with light-gray to white lime, and saturated with salt.

Saltgrass, alkali sacaton, and a scattered stand of mesquite constitute the principal vegetative cover. This provides fair all-year grazing, and most areas are grazed.

Riggs clay (0–0.5% slopes) (Ra).—Riggs clay is extensive in the lower parts of Whitewater Draw.

The 12-inch surface soil is moderately calcareous brownish-gray to grayish-brown granular clay that is dark brownish gray when moist. It breaks to very hard coarse granular or fine blocky aggregates in places. The 12- to 42-inch subsoil is slightly lighter in color, moderately to strongly calcareous, massive, and very hard. Mycelial threads of lime, salt crystals, and reddish-brown and yellow mottling caused by imperfect drainage are common. Below this is the substratum, a mottled light-gray or gray stratified, massive, coarse- and fine-textured material spotted with white lime in the upper part but more uniformly calcareous below. Large prisms are apparent where vertical fractures occur.

In some areas lighter gray or pale-brown, coarse- to medium-textured recent deposits occur on the surface; in others, dark strata resembling the surface soil continue to depths of 6 feet or more. The surface soil cracks open on drying, and sheet and gully erosion are severe.

Use and management.—Saltgrass and alkali sacaton flourish in salty areas, and there is some scattered mesquite, but much of the surface is barren. High salt content, high alkalinity, clay texture, and very slow infiltration make the soil unfavorable for reclamation; consequently, nearly all is used for grazing. Less than 1 percent is being reclaimed. The cost of reclamation would be high even though water occurs at shallow depths.

Riggs clay loam (0–0.5% slopes) (RB).—This inextensive soil occurs along the outer margins of Riggs clay where sediments from sidewashes have contributed materials to give it the clay loam surface texture. The profile characteristics of the series, with the usual variations, characterize this soil. Sheet erosion is probably a little more advanced, but gullies are fewer and less deeply incised than on Riggs clay. Most areas are used for pasture, and the limitations to reclamation are similar to those for the clay.

RUCKER SERIES

The soils of this series occupy small scattered tracts well up on the alluvial fans in association with the Continental soils. They are on smooth slightly elevated areas or long narrow ridges of slightly more rounded relief. The parent materials, predominantly from rhyolite and granite, have been washed in from outside sources and laid down as stratified deposits. The soils are somewhat coarse-textured, especially in the lower subsoil. The content of clay in the subsoil is slight, and these soils are open, porous, and of low water-holding capacity. Lime is usually absent but may occur in very slight concentration in the lower subsoil.

The vegetation consists of perennial and annual grasses, flowering weeds, and scattered mesquite and yucca.

Rucker sandy loam (0–1% slopes) (RD).—The 12-inch surface soil is brown to very pale brown and slightly hard to soft when dry but dark grayish brown to yellowish brown and very friable when moist. It is noncalcareous and rapidly permeable. The organic-matter content is about 0.5 percent. Occasional small pebbles are scattered on the surface. From 12 to 48 inches is noncalcareous very friable pale-brown sandy loam. Below 48 inches are strata of loose very pale brown to brownish-yellow sand and loamy sand. Lime is absent except for occasional slight concentrations in the lower subsoil.

A few inextensive areas are included that have an upper subsoil of weak to moderate coarse granular loam or sandy loam. The lower subsoil materials vary in texture from gravelly sand to sandy loam.

Use and management.—The soil is used exclusively for grazing. The carrying capacity ranges from good to low, the quality depending upon whether controlled grazing has been practiced. Good stands of blue and hairy grama grasses are dominant where grazing is properly controlled. If irrigated, this soil would require frequent irrigation, with

short runs and large heads of water. Management and crops would probably be similar to those for Briscoe sandy loam soils. Limited analyses indicate that available phosphorus is low and that phosphate fertilizers should be used if crops are irrigated. Because of the absence of free lime, any soluble phosphate fertilizer added should be readily available to plants. Most of this soil is near the outer border of the area, where the water lies at considerable depth, and the cost of pumping for irrigation would be comparatively high.

Rucker gravelly sandy loam (0–1% slopes) (Rc).—A higher content of gravel throughout its profile is the chief difference between this soil and Rucker sandy loam. It is closely associated with the sandy loam and occupies gravelly ridges or elevated areas on alluvial fans where much gravel has accumulated. It has slightly stronger slopes than the sandy loam, but it absorbs water rapidly, and very little erosion has occurred. Occasional low wind-blown sand hummocks are common, as are mesquite bushes.

Use and management.—All of this soil is used for grazing. The vegetation of mesquite and annual grasses and herbs affords good pasturage and browse. Most areas are too gravelly and droughty to be suitable for cultivated crops. The depth to ground water is so great that economical irrigation by pumping is practically impossible.

SONOITA SERIES

The sandy loam is the only Sonoita soil mapped. It occurs on well-drained very gently sloping alluvial fans where the parent rocks are acid igneous, mainly granite and other quartz-bearing rocks. This reddish-brown soil has been in place long enough for the free lime to have been leached from the upper 20 to 30 inches and for rock fragments to have decomposed enough to leave a slight accumulation of clay in the subsoil.

The vegetation is predominantly mesquite trees and bushes, blue and hairy grama grasses, and annual grasses and weeds.

Sonoita sandy loam (0–1% slopes) (Sa).—Most of this soil occurs in an area west of Whitewater Draw, but a few scattered bodies are in the extreme northern part of the Willcox Division.

The surface layer extends to an average depth of 15 inches; it consists of noncalcareous brown or reddish-brown weakly fine granular sandy loam, slightly hard when dry and very friable when moist. The organic-matter content is about 0.45 percent. The upper subsoil—starting at 15 and continuing to 30 inches—is noncalcareous, reddish-brown, massive to weakly fine and medium granular, slightly hard gritty clay loam or sandy clay loam. It may be mildly calcareous in the lower part. At 30 to 54 inches, small white lime specks or spots occur in a light-brown to yellowish-red massive sandy clay loam. Underlying this layer are strata of calcareous light-brown sandy clay loam and loam. Variations in surface texture ranging from sandy loam to clay loam are common, and in some areas the subsoil contains occasional angular pebbles and angular particles of granitic sand.

Slight sheet erosion, small shallow gullies, and wind-formed hummocks occur in places. The moisture-holding capacity is moderate.

Use and management.—Mesquite, grama grass, annual grasses, and weeds provide grazing and browse, and the carrying capacity is fair. Cultivated areas produce good yields of alfalfa and fruit. Practices to increase the low supplies of organic matter and available phosphorus are recommended. The soil is hard when dry but is easy to cultivate when moist. Good yields of a variety of crops should be obtained if good irrigation farming methods are followed. As the water lift is about 40 to 60 feet, the cost of pumping should be reasonable.

STEWART SERIES

The Stewart soils are confined to the salty old lake flats and adjacent delta plain at and west of Willcox. They are closely associated with the Gothard soils but are less extensive. Their slow drainage is accentuated by the uneven microrelief caused by sheet erosion and wind action. Slick barren areas and numerous wind-formed sandy hummocks and ridges occur.

These soils have developed from mixed highly variable materials, predominantly from granite or related rocks. They usually have light-gray surface soils over alkali-affected layers that overlie layers of hardpan. These hardpan layers occur at depths of a foot or more and may continue alternately with olive-gray highly dispersed clayey old lake or delta strata. In the sandier soil, the layers of hardpan may be completely replaced by thick rocklike plates or slabs. Hardpans resembling those of the Duncan soils may be encountered in the areas farthest north. Because occurrence of the hardpan is erratic, these soils include some areas where it is absent. The substratum is usually bedded with sandy and gravelly material.

Most areas contain strong concentrations of toxic salts and are very strongly alkaline and dispersed. Because of their very hard platy hardpan, Stewart soils are generally more difficult to reclaim than Gothard soils. Where this hardpan occurs at or near the surface, as it commonly does in the sandier soil, reclamation is impractical except by special methods such as one employed for homesites and gardens in the town of Willcox.

The vegetation is largely saltgrass near the southern or lowest parts of the flats, but alkali sacaton and occasional mesquite, fourwing saltbush, and saltbush are common farther back on the delta plain. All-year grazing is fair, and most areas are used as range land.

Stewart sandy loam (0–0.5% slopes) (Sc).—Areas of this soil occur chiefly near Willcox. The 1- to 2-inch upper surface soil is light-gray, platy, vesicular sandy loam. Beneath this and continuing to about 6 inches is light grayish-brown or pale-brown massive sandy loam. These surface layers are strongly calcareous. At 6 inches is a 2- or 3-inch light-brown layer of rocklike hardness. It occurs intermittently at variable depths and in places outcrops at the surface. At 8 to 24 inches occur stratified old lake sediments of hard, massive to weakly granular, brown to light-gray gritty clay loam. These sediments are generally very strongly alkaline and contain flecks and nodules of lime. The next lower layer is sandy clay loam, mottled with olive, olive gray, or light gray. It is spotted or splotched with lime and interstratified with coarse sand, gravel, and fragmental lime

hardpan. The parent materials are old lake strata largely from granite or related rocks.

This soil is extremely variable from place to place but is most commonly as described above. The subsoil resembles that of the Gothard soils in some areas. The surface soil is loose and sandy in many places.

Though this soil occurs on the salty old lake flats, it has a fairly irregular microrelief because of numerous wind-swept barren slick spots, low hummocks, and ridges of sandy materials. Water stands in the basins for long periods following rains. Toxic salts are concentrated in large quantities, alkalinity is very strong, and the soil is relatively impervious because of its hardpan and highly dispersed clay.

Use and management.—Nearly all areas outside of the town of Willcox are used for grazing. At Willcox, gardens and lawns are planted where top dressings of salt-free soil have been applied and where soluble salts have been removed by leaching.

Reclamation for farming is extremely difficult, and the cost would probably be prohibitive. Water for irrigation occurs at a comparatively shallow depth.

Stewart loam (0–0.5 % slopes) (Sb).—This soil occupies low salty flats and basins in the old lake and delta plain west of Willcox. The 3-inch upper surface soil consists of light-gray vesicular plates of loam. From a depth of 3 down to 14 inches there is weakly granular or massive brown silty clay loam with a somewhat olive cast. This layer is strongly calcareous and flecked with lime in the lower part; it rests upon a 2-inch light-gray to brown rocklike layer. Between 16 and 36 inches is olive-gray gritty strongly calcareous sandy clay loam that contains numerous lime nodules. It is underlain by olive-gray, olive, or light-gray, massive, hard, stratified sediments that have thin layers of lime hardpan similar to those in the substratum of Stewart sandy loam.

The depth to hardpan varies considerably. In places the hardpan occurs as very thin plates between alternating textural strata. Because of the impervious character of the sodium clay and the hardpan, the water that collects in slight depressions after rains usually stands until it evaporates. The soil is highly charged with salts and is very strongly alkaline. Sheet erosion may occur where floodwaters originate on adjacent higher lying lands.

Use and management.—Alkali sacaton, saltgrass, mesquite, and saltbush provide fair all-year grazing. None of the soil is farmed, and reclamation would be extremely difficult and expensive even though ground water occurs at a shallow depth.

TUBAC SERIES

Tubac sandy loam, the only member of the series, occurs in small scattered bodies on the upper parts of alluvial fans near the outer border of the Whitewater Division. Periodic flooding by drainage water is common, and sheet erosion and gullying are active in many places. Some gullies are deeply incised in the subsoil and substratum.

The gravelly and stony lower subsoil and substratum contribute to rapid underdrainage, but the clay upper subsoil effectively retards percolation.

The parent materials are predominantly from rhyolite brought in from mountainous parts outside the area. The Tubac soil is characterized by reddish-brown to dark reddish-brown friable noncalcareous surface soils over red hard clay upper subsoils. The clay is prismatic and high in colloids.

Tubac sandy loam (0–1 % slopes) (TA).—The 2- to 6-inch upper surface soil is noncalcareous brown to reddish-brown sandy loam crusted with vesicular plates. Below this layer and continuing to 12 inches is noncalcareous, strongly granular to blocky, reddish-brown clay loam. From 12 to 24 inches is the upper subsoil of noncalcareous, highly colloidal, strongly prismatic, gritty red clay. The 3- to 4-inch prisms break into smaller ½- to 1-inch prisms that crumble to very angular, colloid-coated small blocks and coarse granules. From 24 to 40 inches are reddish-brown shiny prisms or blocky aggregates of clay, ½ to ¾ inch in diameter, that become mildly calcareous in the lower part of the layer. Below 40 inches the subsoil is highly calcareous, reddish-yellow to pink, stratified clayey sands and gravel firmly held by lime, iron, and silica. Hard caliche layers are common below 6 feet.

Profile characteristics are variable within short distances, and differences occur in various parts of the area. In basins and drainageways, aggrading dark sediments give rise to soils in which the lime occurs at greater depths and the reddish color is darkened. In overgrazed areas or where sheet erosion has removed part of the surface soil, the surface layer may be silty clay loam. Owing to the fine texture of the subsoil, internal movement of water is very slow but is sufficient for effective drainage under natural conditions.

Use and management.—All of this soil is used for grazing. The vegetation consists largely of mesquite and a thin stand of blue and Rothrock gramas and three-awn (pl. 8). A scattered stand of snakeweed, crucifixion-thorn, Mormon-tea, and yucca occurs in some places. The carrying capacity is fair to good, the quality depending upon management. Annual herbs contribute to seasonal grazing in some areas.

Because of the considerable depth to water, the eroded relief, and the prismatic clay subsoil, this soil should be retained as range land for grazing. Controlled grazing, reseeding, and water spreading are recommended.

ESTIMATED YIELDS

Yields obtainable under common management on the various soils in the Sulphur Spring Valley area are given in table 5.

TABLE 5.—*Estimated average acre yields under common management in the Sulphur Spring Valley area, Ariz.*

[Blank spaces indicate that the soil is used almost exclusively for range.]

Soil	Alfalfa	Wheat	Barley	Grain hay	Corn	Grain sorghum	Cotton	Beans	Range carrying capacity [1]
	Tons	*Bushels*	*Bushels*	*Tons*	*Bushels*	*Tons*	*Bales*	*Pounds*	
Briscoe sandy loam:									
Nearly level	5	33	38	1¼	70	1½	¾	1,300	Low.
Hummocky									Do.
Briscoe gravelly sandy loam:									
Nearly level	3	18	20	¾	30	¾	½	800	Do.
Very gently sloping, eroded									Do.
Briscoe loam	4½	25	28	1	40	1¼	¾	1,100	Do.
Deep over Forrest soil material									Do.
Cogswell sandy loam	4	30	30	1¼	50	1½	¾	1,000	Good.
Cogswell sandy clay loam	4	30	30	1¼	50	1½	¾	1,000	Do.
Continental sandy loam									Fair to low.
Continental sandy clay loam									Do.
Eroded									Do.
Continental gravelly sandy loam									Low.
Courtland loamy coarse sand	4½	33	38	1¼	60	1½	1	1,000	Do.
Eroded									Do.
Cowan loamy coarse sand	4½	25	25	1	40	1¼	¾	1,000	Do.
Duncan loam									Do.
Dune sand (partially stabilized)									Do.
Elfrida silty clay loam	5½	33	40	1¼	60	1½	1	1,300	Good.
Elfrida clay loam	5½	33	40	1¼	60	1½	1	1,300	Fair.
Elfrida sandy clay loam	5	33	40	1¼	60	1½	1	1,300	Fair to good.
Elfrida-Gothard loams	4	25	28	1	40	1¼	¾	1,000	Fair.
Forrest clay loam									Good.
Forrest sandy clay loam									Do.
Hummocky									Fair.
Forrest clay									Do.
Forrest gravelly sandy loam									Do.
Frye sandy clay loam	4½	30	35	1½	63	1¾	1	1,500	Good.
Frye sandy loam	4½	25	28	1¼	50	1½	¾	1,250	Fair.
Gothard sandy clay loam									Do.
Gothard sandy loam									Do.

See footnote at end of table.

TABLE 5.—*Estimated average acre yields under common management in the Sulphur Spring Valley area, Ariz.*—Con.

[Blank spaces indicate that the soil is used almost exclusively for range.]

Soil	Alfalfa	Wheat	Barley	Grain hay	Corn	Grain sorghum	Cotton	Beans	Range carrying capacity [1]
	Tons	*Bushels*	*Bushels*	*Tons*	*Bushels*	*Tons*	*Bales*	*Pounds*	
Hooker clay loam	4½	33	38	1½	55	1½	1	1, 250	Very good.
Eroded									Good.
Hooker sandy loam	4½	33	38	1½	65	1½	1	1, 250	Fair.
Karro sandy loam	4	18	23	¾	20	½	½	700	Do.
Hummocky									Low.
Karro loam									Fair.
Karro loamy sand	3½	16	20	¾	48	1	½	900	Fair to low.
Hummocky									Low.
Kelton loamy sand									Do.
Hummocky									Do.
McAllister sandy clay loam	3½	23	25	1	38	1	¾	1, 000	Good.
McAllister sandy loam	3½	23	25	1	38	1	¾	900	Do.
McAllister loamy sand									Fair.
Hummocky									Low.
McNeal sandy loam									Fair.
Mimbres clay loam	5	30	35	1½	68	1½	¾	1, 250	Do.
Mimbres loam	5	30	35	1½	68	1½	¾	1, 250	Do.
Riggs clay									Do.
Riggs clay loam									Do.
Rucker sandy loam									Good to low.
Rucker gravelly sandy loam									Do.
Sonoita sandy loam	5	30	35	1½	70	1¾	1	1, 500	Fair.
Stewart sandy loam									Do.
Stewart loam									Do.
Tubac sandy loam									Fair to good.

[1] Low—less than 5 animal units per section or 3 cow-acre-days per year; vegetation primarily mesquite, catclaw, yucca, saltbush and annual weeds; very little perennial grass. Fair—5 to 8 animal units per section or 3 to 4.5 cow-acre-days per year; some perennial grasses (mostly sacaton, tobosa, and burrograss) but mainly mesquite, yucca, and saltbush. Good—8 to 12 animal units per section or 4.5 to 7 cow-acre-days per year; contains a fairly good ground cover of tobosa, sacaton, and other perennial grasses. Very good—12 to 16 animal units per section or 7 to 9 cow-acre-days per year; contains a wide variety of more palatable grasses as sacaton, tobosa, and grama and such shrubs as mesquite, yucca, and saltbush. Some soil types that should have been in the fair or good classification were classed as low because of prior abuse. Under proper management, it is possible some of the ratings could be increased.

FERTILITY PROBLEMS

The most common fertility deficiencies of most soils of this area are in nitrogen and available phosphorus. Deficiency in available phosphorus may result from excessive lime or from compact, poorly aerated soils in which bacterial activity is low. Such detrimental characteristics as excessive concentration of soluble salts and strong alkalinity are common to only a few soils. They occur in several of the lower lying soils.

Building up and maintaining supplies of organic matter and nitrogen are important in bringing the soils of the area into profitable cultivation. These constituents are furnished in the form of manures, fertilizers, and legumes, all of which encourage the growth of bacteria. Commercial fertilizers are expensive and supply little or no organic matter. Stable manures meet all requirements, but only limited quantities are available. Green-manure or cover crops are useful because they are high in nitrogen and may fix nitrogen in the root nodules. Green manure is not so popular as alfalfa, which permits gradual building up of organic matter and nitrogen over a number of years under a continuous and profitable cropping system. Besides building up nitrogen and organic matter, the alfalfa roots penetrate deeply into the soils to make them more permeable to air, roots, and water. If the hay is fed on the farm or pastured, there is additional value from the manure. Sweetclover can be used effectively in alleviating deficiencies where unfavorable drainage or slight salt or alkali concentrations prevent the use of alfalfa.

Owing to the aridness of the area, total supplies of the minerals needed for soil fertility are moderate to high, but they are not readily available to plants in some of the soils because of an abundance of calcium carbonate. Associated with strong alkalinity is a high dispersion of fine soil material that renders the soils tight and comparatively impermeable to air and water and limits bacterial activity. Carbon dioxide released from roots of plants and from decomposition of organic matter by bacteria reduces alkalinity and promotes granulation of the soil. In consequence, the practices that serve to supply organic matter and nitrogen to the soil also help to make the mineral nutrients more readily available to the plants and to develop an open permeable structure. Even though the Mimbres, Cogswell, Hooker, and to some extent the McAllister soils have a relatively favorable quantity of organic matter, the areas as mapped include a few barren spots in the virgin state that can be improved by additions of organic residues. In the usual rotations that include alfalfa, it is recommended that phosphate fertilizer be applied. Double or treble superphosphate is generally the most effective for soils in this area.

WATER CONTROL AND EROSION

As more or less closed basins characterize much of this area, the problems of runoff, flood control, adequate drainage, and recharge of ground water supply for irrigation are closely interrelated. Changing climatic cycles and wide yearly fluctuations in rainfall have a profound influence on these factors and complicate the effectiveness of any planned control. Over a period of years, the permanent natural

vegetation in this arid country is greatly affected by the minimum rainfall and is not sufficiently dense to cope with the destructive floods that come with the peak of the precipitation. This unbalance promotes rapid natural geologic erosion, the history of which is written in the physiographic land features of this and other areas of the Southwest.

The ground water in these enclosed basins is influenced more by the climatic cycles covering many years than by the annual increase or decrease in rainfall, and any plan for water conservation must tend to create a balance between that drawn upon for irrigation and the probable recharge from the tributary drainage basin. Because the water supply is limited, water should be allocated only to the best soils.

The runoff from higher lying areas during heavy rainfall often accumulates to flood proportions as it enters the surveyed areas, so that dike protection and storm drains are required, especially for soils near drainageways and in low places.

Owing to the slight gradient of the streams, the enclosed basins and broad valleys are but little dissected. The comparative flatness of the valleys has prevented to considerable extent the accelerated sheet and gully erosion that otherwise might have occurred since the ranges were stocked with cattle. Part of the present erosion is normal geologic erosion, but accelerated erosion occurs in most areas that are traversed by roads built on section lines and in some places where homestead lands were plowed and subsequently abandoned. Erosion in the fenced fields results from overgrazing. The capacity of the fenced lands for grazing was greatly reduced by the construction of roads and drainageways. Channels divert runoff instead of permitting it to spread over the surface.

Much of the surface is composed of alluvial fans that descend from the rugged, rather barren mountains. The dark organic sediments of many soils in the low flat drainageways and basins are erosion products from higher grasslands.

Most erosion occurs on the higher fans at the outer margin of the area where ground water is comparatively deep; only a few such areas are cultivated because of pumping costs. Here, the stream channels are constantly shifting, cutting, and filling. These positions, and areas where bank cutting and fissure gullying occur along Whitewater Draw, are the main problem areas for controlling gullies.

Flood control, as practiced by the individual farmers, is done largely by storm dikes and drains. These are often used to collect and divert water to supplement the irrigation supply. Extensive areas of productive land should have protection against storm waters if they are to be developed for irrigation. This probably can be accomplished better by community than individual effort. Perhaps the most valuable soils affected are the Hooker, Mimbres, McAllister, Cogswell, and Elfrida, which occur largely on smooth flats and in basins and are relatively free from sheet erosion and gullying. Gully and sheet erosion most seriously affect soils of the Continental, Tubac, Courtland, and Forrest series, which lie at higher elevations on the outer margin of the area, where the cost of pumping is comparatively high or prohibitive. In addition to sheet erosion and gullying on

these soils, some areas have numerous hummocks and dunes caused by wind action on the sandy sediments deposited by floodwaters.

The soils most seriously affected by both water and wind erosion occur in an almost continuous belt along the higher outer margin west of Whitewater Draw.

CLASSIFICATION OF THE SOILS FOR IRRIGATION

The soils of the area have been placed in seven groups, or classes, in descending order of their suitability for irrigation. The classification is based largely on an appraisal of those characteristics of the soil that affect productivity under irrigation, including physical, chemical, and biological characteristics, such as slope, erosion, drainage, and freedom from toxic salts. There is, of course, some variation in these characteristics within each soil and within each of the land classes. Areas of a soil shown as slightly affected by salts will, for example, be less desirable than those not affected, even though both areas may have been placed in the same general class.

GROUP 1—SOILS EXCELLENT FOR IRRIGATION

The soils of group 1 are:

Elfrida clay loam
Elfrida sandy clay loam
Hooker clay loam
Hooker sandy loam
Mimbres clay loam
Mimbres loam

These soils respond well to proper management. The lay of the land permits uniform and effective distribution of water with a minimum of leveling. Ground water for irrigation usually occurs at shallow depths. The soils absorb moisture readily and hold it efficiently for plant growth. Surface and internal drainage are adequate, and toxic concentrations of salts do not occur.

These are the most fertile soils of the area, though they are not especially high in organic matter. The surface soils in virgin areas contain 1.25 to 1.75 percent organic matter—about as high as can be expected in this climatic environment. The supply of potassium is ample; but like practically all soils of the area, the quantity of available phosphates is low. If group 1 soils are well managed, they should produce very good yields of practically all acclimated crops for many years. The areas in the path of floodwaters will probably require dikes and drains.

GROUP 2—SOILS WELL SUITED TO IRRIGATION

The soils of group 2 are:

Briscoe loam
Briscoe loam, deep over Forrest soil material
Briscoe sandy loam, nearly level
Cogswell sandy loam
Cogswell sandy clay loam
Courtland loamy coarse sand
Elfrida silty clay loam
Forrest clay loam
Frye sandy loam
Frye sandy clay loam
McAllister loamy sand
McAllister sandy clay loam
McAllister sandy loam
McNeal sandy loam
Sonoita sandy loam

Hardpan or clayey layers that restrict root penetration and reduce permeability to water cause this group to be less desirable for irrigation than group 1.

The Cogswell and Elfrida soils have about the same quantity of organic matter as soils of group 1. The Cogswell soils, however, are placed in group 2 because of their higher lime content and hardpan, and the Elfrida soil because of its fine texture. The other soils of this group are lower in organic matter and generally less fertile. Frye and McAllister soils have limited depths above hardpan. Forrest clay loam and Courtland loamy coarse sand have hard and fine-textured subsoils. The upper subsoil of the McAllister soils is very hard and fine-textured. Leveling these soils for irrigation may expose the clay or leave so little surface soil over the clay that the stand of crops will not be uniform. Where the hardpan in Frye, McAllister, and Cogswell soils occurs close to the surface, crops must be given unusual care to obtain yields of good quantity and quality. The hardpan should be blasted if fruit trees are to be planted.

The Briscoe and Sonoita soils are deep and permeable, but they have a lower water-holding capacity than soils of group 1. McNeal sandy loam has a slightly fine-textured upper subsoil and a gravelly porous lower subsoil and substratum. Areas of McNeal sandy loam and Briscoe sandy loam, nearly level, located near the northern and southern ends of the Whitewater Division are slightly less desirable because of droughtiness and ridgy topography.

Soils in this group that are slightly affected by salts should not be difficult to reclaim by flooding and leaching the salts down through the profile. Gypsum may be needed if slick spots develop. Heavy applications of manure and phosphate fertilizer are recommended following leaching.

GROUP 3—SOILS MODERATELY WELL SUITED TO IRRIGATION

The soils composing group 3 are:

Briscoe gravelly sandy loam, nearly level
Continental sandy clay loam
Continental sandy loam
Karro loam
Karro sandy loam
Rucker sandy loam

These soils are less well suited to irrigation than those of group 2 because of the higher irrigation lift for most of the Continental and Rucker soils, the comparatively porous condition and low water-holding capacity of the Rucker and Briscoe soils, and the high lime content and fragmental hardpan of the Karro soils. Only the areas of Karro loam and sandy loam that are free of toxic concentrations of salts and alkali are moderately well suited to irrigation. The soils of group 3 are low in organic matter and phosphates. Good yields of many crops can be obtained by careful irrigation, use of rotations that include legumes at least one-third of the time, and application of phosphate fertilizer. The cost of pumping, or the quantity of water required for irrigation, would be greater than for soils of groups 1 and 2. Dikes and storm drains would be required to protect some areas if they were irrigated.

GROUP 4—SOILS INTERMEDIATE IN SUITABILITY TO IRRIGATION

Group 4 soils are:

Briscoe sandy loam, hummocky
Continental gravelly sandy loam
Cowan loamy coarse sand
Elfrida-Gothard loams
Forrest clay
Forrest gravelly sandy loam
Forrest sandy clay loam

The pump lift of irrigation water would be high for all soils of group 4 except Elfrida-Gothard loams. To level the hummocks and control blowing on the Briscoe soil would be costly. The Cowan soil is loose and porous and would, therefore, require comparatively large quantities of water and frequent irrigation, which would be costly in an irrigation system with many short runs. Parts of the Elfrida-Gothard loams can be made to produce well, but many fields contain barren spots where Gothard loam is intricately associated with Elfrida loam. Such areas and slick spots become more numerous toward the lower part of the valley. In general the higher lying Elfrida-Gothard loams are of better quality than those in comparatively low areas. The Continental soil and parts of the Forrest soils are situated where the cost of pumping would be high. The gravel and fine texture of the Continental soils; the very fine texture of Forrest clay; and the clayey subsoil, the uneven eroded surface, and the slope of other Forrest soils are not desirable. Dikes and storm drains to divert floodwater from the Forrest soils would be more costly than for most other soils of the area.

GROUP 5—SOILS POORLY SUITED TO IRRIGATION

The soils of group 5 are:

Briscoe gravelly sandy loam, very gently sloping, eroded
Continental sandy clay loam, eroded
Courtland loamy coarse sand, eroded
Forrest sandy clay loam, hummocky
Hooker clay loam, eroded
Karro loamy sand
Karro loamy sand, hummocky
Karro sandy loam, hummocky
McAllister loamy sand, hummocky
Rucker gravelly sandy loam
Tubac sandy loam

Various adverse properties, especially wind and water erosion, limit the usefulness of these soils for irrigation. The cost of leveling the land and controlling floodwaters would be exceptionally high. In addition to erosion, profile characteristics of most of these soils are undesirable. Briscoe, Rucker, and Karro soils are extremely loose and porous. Tubac sandy loam has a greater depth to underground water than the other soils of the area, as well as a fine-textured subsoil that is unsuited to irrigation.

GROUP 6—SOILS SUITED TO IRRIGATION ONLY AFTER COMPLEX RECLAMATION PRACTICES

The soils of group 6 include:

Duncan loam
Gothard sandy clay loam
Gothard sandy loam
Riggs clay
Riggs clay loam

Practically all the soils that contain moderate or large quantities of toxic salts or alkali, or of both, belong to this group. They become suited to irrigation only after use of reclamation methods. Duncan

and Gothard soils have adverse structural properties that are difficult to improve. Most Riggs soils are moderately or strongly affected by salt or alkali and would be difficult to reclaim. Reclamation is not impossible but is generally not recommended because of the expense.

GROUP 7—SOILS NOT SUITED TO IRRIGATION

The soils of group 7 are:

Dune sand (partially stabilized)
Kelton loamy sand
Kelton loamy sand, hummocky
Stewart loam
Stewart sandy loam

The Kelton soils and Dune sand (partially stabilized) are too sandy or have too many dunes to be developed for irrigation. Stewart soils are so strongly alkaline, so uneven in surface relief, and have such erratic hardpans that their reclamation is almost impossible economically. Some Kelton soils have been leveled and are now being sprinkler irrigated.

IRRIGATION

Irrigation is accomplished largely by pumping, but some storm waters are diverted to supplement water from underground sources. Where farming depends upon the supply of underground water, a study of that supply and its relation to the quantity of water pumped is important.

The northern and southern parts of Sulphur Spring Valley [5] are separated by a geologic dike, or low buried hills, near Pearce. Because this dike separates the northern part of the valley (the Willcox Basin) from the southern part (the Whitewater Draw), and because these two areas have different sources of underground water, each is discussed as a separate unit.

WILLCOX BASIN

The surface drainage in the Willcox Basin is into the Willcox Playa, a dry lake southwest of Willcox about 50 square miles in area. Most of the water flowing into this basin, which occupies the lowest part of the valley, evaporates and leaves an accumulation of salt. The valley fill consists of water-transported debris from the nearby mountains. It is of variable mineralogical composition and texture. Most underground water is in the gravel of old buried stream channels. Artesian water is found occasionally. Artesian wells have a maximum flow of 80 gallons a minute, whereas some of the pumped wells have been known to yield 1,200 gallons a minute.

The demand for water varies with the agricultural activity in the valley. The first well was dug in 1872, but there was little farming in the Willcox Basin until 1905 when a few homesteaders moved into the region. By 1910 there were 60 pumping plants, and in 1920 at least 3,500 acres were under irrigation. The cultivated acreage had been reduced to about 2,500 by 1926 and remained at this figure until 1940. By that time many of the old dug wells, which had been

[5] JONES, R. F., and CUSHMAN, R. L. GEOLOGY AND GROUND WATER RESOURCES OF WILLCOX BASIN, COCHISE AND GRAHAM COUNTIES, ARIZONA. U. S. Geol. Survey. 35 pp., illus. 1947. [Processed.]

pumped with centrifugal pumps powered with internal combustion engines, failed to produce adequate supplies of water because of the gradual lowering of the water table. In 1940, however, electric power became available, and the conversion to drilled wells, electric motors, and modern pumps became general. Since 1940 all new wells have been drilled and cased from the surface and fitted with turbine pumps.

The irrigated acreage reached approximately 5,000 acres by 1946; 90 irrigation wells, both artesian and pumped, supplied the water. This expansion has continued, and in 1948 the irrigated area was about 10,000 acres.

The Willcox Basin, or Playa, has no surface outlet; so surface water as such would not be lost to the area. There is a possibility, however, that some ground water may be lost from the basin. It may flow northward through the valley of Arivaipa Creek, southward to Whitewater Draw, or eastward to San Simon Valley.

The older valley fill in the Willcox Basin, the principal aquifer in the area, consists of permeable discontinuous but interconnected lenses of sand and gravel. These are interbedded with comparatively impermeable layers of clay and silt.

The depth to water in the Willcox Basin is variable. Most irrigation water is pumped from wells less than 150 feet deep and not under artesian pressure. The water table is near the surface at the Willcox Playa and becomes increasingly deep at greater distances from it, except in cases where impermeable interbedded materials are sufficiently extensive to form perched water tables.

The usual means of recharging the ground water table are stream flow and surface runoff, precipitation, and irrigation water. The mountains on the eastern side of the valley are higher than those on the western and receive much more precipitation. Rain and melting snow keep the mountain streams flowing for about 5 months each year, but the water seldom flows more than 3 or 4 miles into the basin before it is all absorbed. Torrential rains, running off as sheet floods, are largely absorbed by the coarse materials near the mountains and in this way contribute to the recharge of the ground water table. It is difficult to estimate what effect the precipitation that falls on the valley floor has on recharging the water table. A large part of it spreads out over the surface of the ground and evaporates, whereas a lesser quantity seeps into the ground and eventually reaches the water table. Ground-water losses may also occur by means of springs or plants. Most of the pumping in the valley is at some distance northwest of Willcox; there may therefore be a tendency for the water table, which is deeper at greater distances from the playa, to be replenished from water under or near the playa. Turner and others [6] found that 25 percent of the irrigation water applied to the soil eventually reaches the ground water table. No estimate has been given for the Willcox Basin.

The quantity of water removed by artificial discharge in 1946 was 15,500 acre-feet. About 500 acre-feet of this was from artesian wells and the rest from pumped wells. The artesian wells range from 380

[6] TURNER, S. F., and others. GROUND WATER RESOURCES OF SAFFORD AND DUNCAN-VIRDEN VALLEYS, ARIZONA AND NEW MEXICO. U. S. Geol. Survey. 50 pp. (+ 58 pp. of tables). 1941. [Processed.]

to 700 feet in depth and from 4 to 16 inches in diameter; the pumped wells range from 50 to 250 feet in depth and from 12 to 16 inches in diameter.

Water-level measurements have been made in the Sulphur Spring Valley over a period of years. In 1910 Meinzer and Kelton [7] made measurements for comparison with some made in 1875. As there was little pumping in the area at that time, the lowering of the water table was insignificant. Measurements made by the U. S. Geological Survey in 1942 showed declines in the water table, but they were small in comparison to those estimated from measurements made in 1946. The greatest declines naturally were in the heavily pumped areas northwest of Willcox.

The water in the Willcox Basin is of good quality for irrigation. Many analyses indicate a very satisfactory total salt content, usually less than 1,000 parts per million, and most analyses show a favorable sodium-calcium ratio. Waters from wells near the playa, however, contain more salt and have a higher percentage of sodium than those at a greater distance. Some water is relatively hard, an asset for irrigation but not so desirable for domestic purposes. Some of the water contains more than 1.0 part per million of fluorine; and if it is consistently used by children during the time their permanent teeth are developing, mottled enamel may result.

WHITEWATER DRAW [8]

The drainage basin of Whitewater Draw lies south of the Willcox Basin and north of the International Boundary. It is bordered on the east by the Chiricahua, Pedregosa, Swisshelm, and Perrilla Mountains and on the west by the Dragoon and Mule Mountains.

The Whitewater Draw rises in the Chiricahua Mountains in the northeastern part of the drainage basin, drains southward, and leaves Arizona about 3 miles west of Douglas. In the northern part of the basin, the channel is indistinct, but in the southern part it is joined by small tributaries from the mountains on either side of the valley and becomes a channel 10 to 20 feet deep and 30 to 100 feet wide in places. It carries water only during a part of the year. Water enters the old valley fill through the sand washes and the coarse sediments near the mountains and is stored until used or lost by leakage. The only leakage from the basin is by surface runoff and a small underground flow in the Whitewater Draw.

The water-bearing strata are connected by lenses of permeable sand and gravel, and pumpage from one well may affect a great many other wells in the basin. The loose strata of water-bearing gravel are interbedded with relatively impermeable layers of clay and silt.

Losses of water from this basin may occur by natural or artificial means. An appreciable but undetermined loss occurs through evaporation. Another loss is through the transpiration of water by grasses, mesquite, and other plants. Pumping for irrigation probably accounts for the greatest loss. Ground water has been pumped in

[7] See footnote 3, page 4.

[8] Information from U. S. Department of Agriculture, Bureau of Agricultural Economics, Water Facilities Area Plan for Whitewater Draw Watershed, Cochise, Ariz., July 1940; and U. S. Department of Agriculture Soil Conservation Service, Memorandum from Harold E. Elmendorf to R. W. Hollenburg, Jan. 30, 1947.

the basin for irrigation since about 1911, but expansion of agriculture has been slow. Before 1939 the annual pumpage did not exceed 5,000 acre-feet; but in 1946 about 12,500 acre-feet was pumped from 166 wells, and 83 of the pumps were powered by electric motors. Individual pumps do not discharge large streams of water, and the average flow of the irrigation wells in the area is 280 gallons a minute.

The depths of the wells vary from 50 to 650 feet, but all water is pumped from the interconnected water-bearing strata that form a common ground-water reservoir.

The ground-water table was lowered an average of 2.7 feet during the period 1911–39. The greatest lowering was between Elfrida and the Double Adobe area, where the water table was lowered about 8 feet in some wells. This is three times the annual decline of the earlier period. In the parts of the valley that were not pumped, the decline in the water table was small. With the rapid increase in irrigated acreage (11,000 in 1948), the ground-water level has undoubtedly lowered considerably.

The annual safe yield of water in the Whitewater Draw drainage basin has not been definitely established. It is safe to predict, however, that if irrigation agriculture is much further expanded, the water table may drop so low that the cost of pumping will become prohibitive. The depth from which it is economically feasible to pump water and the aggregate acreage that can be irrigated without greatly lowering the underground water supply should be established, and the water allocated accordingly. An effort should be made to allocate water to soils of good quality.

The quality of water in this drainage basin is very similar to that in the Willcox Basin. The salt content is generally low, that is, below 1,000 parts per million, although some samples contained more than 3,000 parts per million. One of the greatest objections to the use of these waters for irrigation is their relatively high sodium to calcium ratio. The relatively high sodium content may cause the soils upon which the water is used to become dispersed and comparatively impervious to air and water. Gypsum corrects this condition. Because deposits occur 5 miles east of Douglas, gypsum is comparatively cheap and can be used to reclaim irrigated soils that become high in exchangeable sodium.

The toxic content of fluorine makes much of the water objectionable for use by children, as it causes mottling of the enamel on their teeth.

SALTS, ALKALI, AND DRAINAGE

Most soils in arid regions are relatively rich in soluble salts, and in places these salts are highly concentrated. A large part of the salts set free by decomposition of the soil minerals remains in all but the most porous soils, as rainfall is too low and evaporation too high to allow deep penetration of water and consequent leaching of the salts. High salt concentrations that are toxic to plants commonly develop only in lower lying areas where drainage is slow. In such places the evaporation of salt-charged water results in a gradual accumulation of the salts either in or on the soils. Where the water table is high, water that contains salts rises through the soil by capillarity and leaves the salts at the level where it evaporates. These salts are readily

dissolved and moved in solution to any part of the soil profile and, especially under irrigation, are constantly being shifted.

Toxic concentrations are spoken of as accumulations of salts, and the soils in which they occur are known as saline soils. Where slick spots are common and salts not apparent, and in places where dark-brown stains occur, the soil is affected by alkali and is known as an alkali soil. Saline soils have an accumulation of the neutral salts of sodium, predominantly chloride and sulfate; whereas the alkali soils, or black alkali soils, are high in exchangeable sodium or in sodium carbonate. It is the solution of organic matter by very strongly alkaline substances like sodium carbonate that causes the dark-colored stains in some soils, and hence the name "black alkali". In this area, saline soils, alkali soils, and soils that are both saline and alkaline are common.

The accumulation of salts in the soil is known as salinization. So long as a high concentration of neutral salts exists, the alkalinity of the soil is usually low, and the soil is usually permeable, granular, and well aggregated. When leaching occurs, the concentration of the neutral salts may be lowered and the degree of alkalinity is frequently increased. If considerable sodium (or alkali) is present in an exchangeable condition on the clay particles, a dispersion or breaking down of the soil aggregates and closing of the pore spaces may occur. Such dispersed soils become dense, comparatively impervious, and resist the penetration of roots, air, and water. The process is called alkalization, and the resulting soils are known as alkali soils. Most of the salty soils of the area are also moderately alkaline and hence subject to such unfavorable developments if managed unwisely.

Alkali-affected soils may be unfavorable for plant growth even where their total content of soluble salts is low, for the alkali is generally more toxic to plants than the neutral salts in saline soils. In addition, the dispersed hard alkali soils practically exclude penetration of water and thus restrict the growth of plants.

The tolerance of plants to salts depends on such factors as the kind of plant, the kind and concentration of salts in the soil and their location in the soil profile, the texture of the soil, moisture condition, temperature, evaporation, and the salt content of irrigation water. A concentration of salts in the deep subsoil may not interfere with the growing of shallow-rooted crops such as small grains and sorghum; whereas it may interfere with deep-rooted plants such as alfalfa and fruit trees. A given quantity of soluble salt is more toxic in a coarse than in a fine-textured soil because the soil solution is more concentrated in the former. Salts produce more serious effects when the soils are comparatively dry and the weather hot and dry.

The chemical and physical properties of the soils should be given first consideration in the problem of reclamation. Alkali-affected soils that have a fine texture are very difficult to reclaim. Many alkali soils in this area have hardpans in addition to their fine texture.

The general distribution and concentration of salts and alkali in the area are shown on the soil map by boundary lines and symbols in blue. The acreage affected includes about 27 percent of the total area surveyed.

Areas free of toxic concentrations are shown on the map by the symbol F. In addition, three grades of toxicity are shown. Slightly

affected areas on which some harmful effects upon crop plants may be expected are shown by the symbol S; moderately affected areas in which more serious effects on both plants and germination may be expected are shown by M; areas strongly affected are shown by A.

The F areas, in which no toxic effect on vegetation is apparent, have a concentration of soluble salts below 0.2 percent of the weight of the dry soil in the upper 6 feet and are not strongly alkaline. The slightly affected S areas include soils having a salt concentration ranging from 0.2 to 0.4 percent, or inextensive areas of strong alkalinity, or both. The moderately affected M areas include soils having an average soluble salt content ranging from 0.4 to 0.8 or 1.0 percent, or moderately extensive alkali-affected areas, or both. Their reclamation is problematical, but some success may be attained where soil structure is favorable and hardpan absent. The strongly affected A areas contain excessive quantities of soluble salts or extensive areas of strong alkalinity, or both. They have very little possibility for economical reclamation and should be avoided.

This mapping of salt concentration is based upon field observation of topography, vegetative growth, surface appearance, and profile characteristics of the soils and on determination by the salt bridge of total soluble salt content in a 6-foot section.

Leaching with irrigation water under proper drainage conditions is the most important part of any system of reclamation. Effective drainage is needed to effect free downward leaching and to carry away the excess salts. Besides the methods usually employed, various chemical treatments have been shown to be effective in reclamation, especially where the alkalinity of the soil is very strong. Applications of gypsum or sulfur tend to neutralize the alkalinity and make the soil more permeable. Where exchangeable calcium is low in alkali-affected soils, gypsum is usually very beneficial and most commonly used.

Most poorly drained soils are in the flood plain of Whitewater Draw or surrounding the Willcox Playa. These areas are highly charged with salts, and the soils are impermeable or very slowly permeable and therefore difficult or impossible to reclaim. Reclamation of soils near the Wilcox Playa may never be possible because of lack of a drainage outlet. The saline soils of Whitewater Draw probably could be reclaimed, but extensive areas are fine-textured and slowly permeable, and their reclamation would be slow and costly.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of the environment acting upon soil-forming materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by: (1) The physical and mineralogical composition of the parent soil material; (2) the climate under which the soil material has accumulated and existed since accumulation; (3) the relief, or lay of the land, which influences the local (or internal) climate of the soil, its drainage, moisture content, aeration, susceptibility to erosion, and exposure to sun and wind; (4) the biologic forces acting upon the soil material, and on the plants and animals living upon and in it; and (5)

the length of time the climatic and biologic forces have acted on the soil material.

The Sulphur Spring Valley area lies in the Reddish Brown soil zone,[9] which is characterized by a relatively hot arid climate and thin grassland and sparse desert shrub vegetation. A few of the soils have characteristics indicating that they are transitional between the Reddish Brown and the Red Desert soils. The soils, like those of other areas in the arid Southwest, have certain general characteristics in common in spite of the variations in parent materials, relief, drainage, and the length of time the materials have been exposed to weathering and soil development. Most of the soils are relatively light-colored and low in organic matter as compared with the soils of the more humid grasslands, but they are somewhat darker and richer in organic matter than the Red Desert soils that occur in drier and hotter areas. Some of them have a light reddish-brown color, but others are darker and grayer owing to accumulations of organic matter from grass or to deposition of sediments relatively rich in organic matter. The soils are characterized by comparatively little leaching and contain a relatively high percentage of alkali and alkaline earth elements.

Calcium carbonate is present in most of these soils, and in some of them the content of sodium salts is very high. In all soils except those from the more recent alluvial and wind-laid deposits, calcium carbonate has accumulated in a definite light-gray horizon. In places it is cemented into hardpan or caliche. In some of the soils the surface soil is free from calcium carbonate and is neutral or slightly acid. In these same soils, the subsurface generally is mildly alkaline and the subsoil distinctly alkaline. Many of the well-developed soils have a subsurface or upper subsoil that is redder and more compact than the surface soil and contains a comparatively high concentration of colloidal clay.

The parent materials from which the soils of this area have developed have been transported by water and wind and laid down largely as alluvial fans and alluvial plains. The country rock in the mountain chains that border the valley is complex and varied, and the soil-forming materials derived therefrom are similarly complex and mixed. The nearer the transported materials are to their source, however, the more like the parent rock they are. The country rock consists largely of granite and similarly related or equivalent crystalline rocks, rhyolite, andesite, and quartzite, with some limestone and sandstone in places.

Much of the surface of the area is composed of alluvial fans that descend from the rugged mountains. At first these fans slope steeply, then more gradually, and finally they flatten and coalesce to form alluvial plains or playas as they approach the axes of the valleys. The coarse stony, gravelly, or sandy materials are dropped by drainage waters on the higher and steeper parts of the fans or ridges; the finer silt, clay, and colloidal materials are carried farther down and finally settle on the alluvial flats and playas where drainage is slow. Almost impervious clays highly charged with salts occur in many of these low flat areas. The valleys are deeply filled with alluvium, and

[9] UNITED STATES DEPARTMENT OF AGRICULTURE. SOILS AND MEN. U. S. Dept. Agr. Yearbook 1938, 1232 pp., illus.

the stream channels are constantly shifting, cutting, and filling. Many well-developed soils are buried by fresh sediments, and erosion is removing the upper layers and exposing old claypans, hardpans, and other soil horizons in other places.

The limited rainfall of the area causes only relatively shallow leaching of the soils, but this leaching is accentuated in places by runoff from higher areas. Runoff, flooding the lower fans and the low flat alluvial plains and playas, penetrates the soils to considerable depth and brings about deeper leaching than is characteristic of associated soils that receive no supplementary water. The grass and sparse desert or semidesert shrub vegetation contribute only relatively small quantities of organic residues to the soils but more than in the lower drier region. Rapid oxidation is promoted by the long periods of heat and sunshine, thus causing organic matter to disappear rapidly and minerals to become highly oxidized and dehydrated. Cobbles and gravel exposed on the surface over a period of time acquire a dark coating of desert varnish, an almost black coating of oxidized iron and manganese minerals.

The well-developed zonal soils have a relatively thin light-colored or bleached surface under which is a browner horizon resting on a distinctively reddish-brown plastic clayey horizon. The content or concentration of calcium carbonate varies with the nature of the parent material and the stage of profile development. Lime is not normally in the surface soil of such soils, but it is accumulated in seams, veins, netting, spots, splotches, or nodules in the subsoil. The older and more developed soils have lenses of marly to nodular character, and lime hardpans are common. Soils from recently accumulated water or wind deposits are characterized by the absence of lime or by its uniform dissemination throughout the profile. As soil development progresses, definite lime-accumulation horizons form in the soil.

Theoretically, the normally developed soils of the region should occur in relatively smooth well-drained areas that are practically free from erosion or deposition and are seldom, if ever, overflowed by waters charged with calcium carbonate and soluble salts. Within the area surveyed, few positions meet these requirements for so-called normal development, and soils that have the full impress of the unmodified climatic and biologic environment are limited. The microclimate, microrelief, variable vegetation, erosion, deposition, overflow or percolating waters often charged with lime and sodium salts, subdrainage, and character of parent materials apparently modify soil development to such an extent that it is difficult to identify a normally developed soil.

Such soils as the Forrest, largely from mixed materials from granite, sandstone, quartzite, and rhyolite, and the Continental and McNeal, largely from rhyolite, seem to represent more nearly the normal than others in the area. At least they are representative of soils on large areas of smooth alluvial fans where drainage is good and overflow is not frequent or heavy. They are noncalcareous in the upper 15 to 20 inches, the exact depth probably depending on the soil texture and the quantity of penetrating water. In the lower part of that zone, clay and colloids are concentrated in a layer that is more dense, compact, and plastic. The color is bright reddish brown in

contrast to the duller reddish brown or brown of the surface soil. This compact and plastic clayey material continues downward into the zone of calcium carbonate accumulation. The carbonate appears in the form of veins, seams, flecks, spots, or mottlings of white or light gray in the brownish red to red of the soil mass. In the lower part of the solum, a high concentration of uniformly distributed lime occurs, the reddish clayey material diminishes with depth, and brown and gray become dominant. Slight cementation is not uncommon above the substratum.

Description of Forrest clay loam on a gently sloping alluvial fan under a cover of scattered grass and brushy mesquite:

A_{11} and A_{12} 0 to 10 inches, reddish-brown weakly coarse granular to medium fine blocky, friable, noncalcareous clay loam capped by a light-brown somewhat platy and vesicular surface crust; upper few inches under the crust are in most areas darkened by organic residues from the grass cover.

B_{21} 10 to 18 inches, brighter reddish-brown noncalcareous clay loam of blocky to faintly prismatic structure; prisms average 1½ inches in diameter and are coated with colloidal material.

B_{22} 18 to 24 inches, similar to horizon above but with white spots or flecks of lime.

B_{23ca} 24 to 54 inches, reddish-brown to brown gritty clay with vertical fractures and white lime spots and soft nodules.

C 54 to 74 inches, brown clay embedded with many soft lime nodules.

The Continental soils, largely from rhyolite, and the Courtland, from granite, have very similar profiles except for parent material. They appear to have reached a more advanced stage of development than the Forrest soils. They occupy slightly higher places on the alluvial fans and probably have been acted upon by the forces of soil formation for a longer period, but they have a native cover similar to that on Forrest soils. In addition, they are more deeply leached than the Forrest soils. They are practically neutral at the surface. Lime appears at depths of 24 to 36 inches or more, and a higher lime concentration is in the lower subsoil and substratum. The Continental and Courtland soils probably represent soils in which the end point may have been reached in the normal concentration of lime, and increased accumulation must be attributed to other factors. The reddish color throughout and the highly colloidal character of the material indicate advanced stages of hydrolysis, oxidation, and dehydration.

Profile description of Continental sandy clay loam:

A_1 0 to 10 inches, light reddish-brown (5YR 6/4, dry)[10] to dark reddish-brown (4/3 to 3/4, moist), noncalcareous sandy clay loam; weakly medium to fine granular; crumbly when dry; very friable when moist; pH 7.6; organic-matter content about 0.8 percent.

B_1 10 to 20 inches, yellowish-red (5YR 5/6, dry) to reddish-brown (4/4, moist), noncalcareous heavy clay loam or sandy clay high in colloids; blocky to weakly prismatic; very hard when dry, firm to friable when moist; pH 7.8; organic-matter content about 0.6 percent.

B_{21} 20 to 24 inches, similar to horizon above or of clay texture and faintly to moderately mottled with light-gray to white flecks of lime carbonate; pH 8.2; organic-matter content about 0.4 percent.

B_{22ca} 24 to 28 inches, similar to above horizon but strongly mottled and veined by accumulated lime; pH 8.3.

[10] Munsell color notation.

B_{23ca} 28 to 38 inches, pink (5YR 8/4 to 7/3, moist) weakly lime-cemented or nodular clay loam; hard to very hard when dry, firm to friable when moist; contains moderate number of rounded pebbles; pH 8.3.

C 38 to 60 inches, gravelly sandy loam of same color as horizon above but contains much less lime; massive; lime somewhat disseminated; slightly hard when dry, friable to very friable when moist; pH 8.3.

The Tubac soil, which occurs in association with the Continental soils and is from similar materials, appears to be more strongly developed. The noncalcareous reddish clay B horizon has a pronounced prismatic structure, is highly colloidal, and is very hard when dry.

The profile of the McNeal soil is very similar to that of Continental soils, but the B horizon is less compact and lower in colloids. The McNeal soil occupies smooth broad ridges that descend well into the valley plain and it is closely associated with the Elfrida soils in many places. It has a noncalcareous brown to reddish-brown surface soil over a pronounced reddish-brown, colloidal, sandy clay loam subsoil. In places the upper subsoil is weakly prismatic clay loam. The lower subsoil contains streaks and spots of lime and in places soft nodules. Below the lime horizon is stratified sand and gravel that become increasingly coarse with depth. The parent materials are mixed; rhyolite and quartzite are predominant.

The Elfrida soils occur in lower situations than the McNeal and are frequently flooded by runoff from the higher lying soils. These waters often carry sediments that have somewhat retarded the development of the Elfrida soils and made them less oxidized than the McNeal soil. They are more highly organic in the surface soil and duller or less red in the subsoil.

Profile of Elfrida clay loam developed under a moderately dense stand of tobosa grass:

A_{11} 0 to 1½ inches, noncalcareous light grayish-brown crust of finely granular clay loam or loam; pH 7.

A_{12} 1½ to 12 inches, light grayish-brown noncalcareous clay loam; coarse to medium granular; hard when dry but friable when moist; abundant roots and worm holes; pH 7.9; organic-matter content about 1.3 percent.

B_{21} 12 to 24 inches, brown noncalcareous heavy clay loam; breaks into ¼- to ½-inch angular blocks; hard when dry but friable when moist; pH 8.0; organic-matter content about 1.0 percent.

B_{22ca} 24 to 36 inches, pink heavy clay loam abundantly spotted with lime; hard and breaks into large angular fragments; pH 8.1; organic-matter content about 0.35 percent; calcium carbonate, about 12 percent.

C 36 to 80 inches, light-gray to light brownish-gray massive clay loam with numerous white lime streaks and spots; pH 8.2; organic-matter content about 0.25 percent; calcium carbonate, about 12 percent.

Soils that have not reached the stage of development of the Elfrida and other soils heretofore described include the Hooker, Cowan, Rucker, and Briscoe with slight or no accumulated lime and the more advanced Sonoita and Mimbres with slight accumulations of lime and other weak zonal characteristics.

Hooker, Cowan, Rucker, and Briscoe soils consist of almost unmodified deposits of various materials. The soil profiles are characterized by geological stratification rather than by developed soil

horizons. They are, at most, only feebly calcareous in the lower subsoil.

The Hooker soils have developed in smooth basins and flats from dark fine-textured soil materials of mixed origin, carried in largely from higher grassland areas. Besides the inherent dark color and moderate organic-matter content contributed by this alluvium, organic residues have probably been added to the surface soil by the dense growth of grass. These soils have occasional barren areas that are slowly permeable to water. These areas are apparently not caused by sodium clay; they may result from continued alternate flooding and baking under intense summer heat.

The Cowan soil developed from stratified materials derived largely from granite, granodiorite, and related rocks. Its open porous character and elevated position have permitted deep aeration and oxidation, and because of this the soil is reddish brown. Definitely developed horizons are very faint or have not formed, and little or no lime has accumulated.

The Rucker soils developed on gravelly alluvium, largely from rhyolite, that was laid down on the upper fans or as elongated ridges. They have brown to very pale-brown surface soils and pale-brown to yellowish-brown subsoils. Their color appears to be related to the parent rocks. The soils should be well oxidized but are definitely less red than the Cowan soil. The Rucker soils usually are free of lime to depths of 60 inches or more.

The Briscoe soils are lighter colored than the Hooker, Cowan, and Rucker and are calcareous in the subsoil in many places. They developed from materials of mixed origin, including considerable rhyolite, quartzite, and limestone, and occur on broad nearly level ridges and other elevated areas. They have light-brown surface soils over very slightly lighter colored, coarser textured, stratified subsoils that have a very slight accumulation of lime. They support a light cover of annual grasses and a scattering of perennial grasses and desert shrubs.

The Sonoita and Mimbres soils are more or less reddish because of hydrolysis and oxidation, and the lower horizons contain some accumulated clay and colloids. The surface soils have acquired a brownish color from organic residues left by decayed plants. Calcium carbonate has accumulated in the subsoil, generally in netted, veined, or finely flecked patterns.

The Sonoita is an inextensive soil closely associated with the Cowan series, and it developed from similar materials. It occupies more nearly level areas and has received larger quantities of moisture. It has therefore undergone comparatively deep leaching of lime carbonate and has a marked degree of hydrolysis in the subsoil. The Sonoita soil has a noncalcareous brown to reddish-brown surface soil over a reddish-brown slightly fine-textured upper subsoil. The lower subsoil is moderately fine textured and mildly calcareous; it shows fine threads or veins of lime carbonate. The upper few inches of Sonoita sandy loam from a virgin area are slightly acid (pH 6.1), and the organic-matter content is about 0.45 percent.

The Mimbres soils, the parent rocks of which are rhyolite, are slightly more advanced in development than the Sonoita soil. They are developed under grass cover and have brown, noncalcareous,

granular surface soils that contain about 1.5 percent of organic matter. The subsoil is light brown, blocky to weakly prismatic, and mildly calcareous in the upper part; it contains many lime veins in the lower part. The lower subsoil is somewhat stratified and grayer or lighter brown. The lime may be in streaks and spots or occur as uniformly disseminated finely divided particles.

Many soils in the Sulphur Spring Valley area are strongly calcareous in both surface soil and subsoil. In some places erosion has exposed limy subsoil layers; in others there has been overwash of calcareous material; and in still others evaporation of lime-charged ground waters or surface waters has left calcium carbonate in the soil. Normal leaching has been sufficient to cause some downward movement of the calcium carbonate. Calcium carbonate in most of these soils is largely a product of weathering of soil material or of soil development, as there is very little calcareous sedimentary rock. The accumulation of calcium carbonate is caused largely by water. Whether precipitated from downward percolating water in normal soil development, precipitated from surface or underground waters, or produced by hydrolysis of more complex minerals in place, accumulations are constantly increasing.

Soils of the Karro series are unusually high in lime in the surface and subsoil layers. They are very pale brown to light gray. The fine-textured mixed alluvial-fan materials from which the soils have developed include rhyolite, quartzite, and probably some limestone, for limestone strata occur in the nearby mountains. The lime in the strongly calcareous surface soils and the marly subsoils of the Karro series may have been translocated by laterally moving seepage water.

Soils with hardpan include the Frye, McAllister, and Cogswell. They have a series of cemented layers in the lower subsoils and substrata. These soils are relatively free from toxic salts and do not have the adverse properties resulting therefrom.

The Frye soils occupy the more elevated positions, and their reddish color is due to oxidation and dehydration. They have light-brown to reddish-brown noncalcareous surface soils over highly colloidal, blocky, yellowish-brown or reddish-brown upper subsoils. The clayey upper subsoil, which also occurs in the McAllister soils, is a product of active hydrolysis. The upper subsoil is underlain abruptly by indurated lime hardpans. These hardpans are extremely variable in thickness; they alternate with uncemented interplate materials and often have glazed surfaces.

The McAllister soils occupy lower and more nearly level areas than the Frye soils and therefore have received more runoff and supported a more luxuriant stand of grass. This has resulted in a darker color and a higher organic-matter content. The hardpan is a product formed by precipitation from solution and appears to be lime-cemented but may be partly cemented by iron and silica. It is very hard and consists of platy to massive formations that alternate with softer sandy loam or sandy clay loam material.

The Cogswell soils are very similar to McAllister soils, but their surface soils are darker and higher in organic matter. Their upper subsoil is not so hard or so fine-textured but more granular and more readily permeable. The underlying fragmental hardpan is similar.

Of the soils in the salty alkaline playas and low basins of the area, all but the Riggs have definite morphological characteristics associated with alkali-affected soils. Salinization does not materially alter profile development, but during the process of leaching that may follow, the adverse effects of sodium saturation and alkalization may appear. Most of the salts accumulated in the soils during the period when a high water table occurred in the area. When the water table receded, salts were leached downward, and the sodium clay became dispersed and was concentrated in the upper subsoil. Subsequent hydrolysis of the sodium clay and movement of organic matter and iron from the soil immediately over the clay horizon has given rise to a gray siliceous horizon in the Gothard and Duncan soils.

Description of Gothard sandy loam:

A_1 0 to 5 inches, very pale-brown (10YR 8/3, dry) to brown to pale-brown (5/3 to 6/3, moist) noncalcareous sandy loam; appears massive but breaks to medium and fine granules; hard when dry, friable when moist; where surface is barren, upper 1 to 3 inches are platy and vesicular; pH about 8.4 where comparatively free from salt and alkali.

A_2 5 to 7 inches, light-gray (10YR 7/2) noncalcareous silt loam; massive or platy and vesicular; sharp-edged but floury when crushed; slightly hard when dry, very friable when moist; pH about 8.4.

B_2 7 to 10 inches, light-brown (7.5YR 6/4) to yellowish-brown (10YR 5/4) when dry and brown (7.5YR 5/4) to dark yellowish-brown (10YR 4/4) when moist, noncalcareous clay loam to clay; columns average 3/4 inch in diameter, are strongly coated with colloids, and crumble easily to coarse granules; pH about 9.2.

B_{3ca} 10 to 18 inches, heavy clay loam to clay with same color as horizon above; weakly columnar to strongly coarse granular material moderately to strongly mottled with light-gray accumulated lime; granules hard when dry, friable when moist; pH about 9.6.

C_1 18 to 30 inches, light yellowish-brown (10YR 6/4) to light-brown (7.5YR 6/4) strongly calcareous loam; massive; slightly hard to soft when dry, very friable when moist; pH 9.6 to 10.

C_2 30 to 60 inches, similar to horizon above or slightly lighter or darker in color and slightly coarser or finer in texture; may be either alluvial or lacustrine in origin; pH 10.

Closely associated with Gothard soils are Duncan and Stewart soils. The surface and upper subsoil horizons of the Duncan soil are very similar to those of the Gothard, but the subsoil lime is segregated into a fragmental hardpan. The surface horizons in the Stewart are more gray than in the Gothard, and thick sandstonelike plates or slabs have developed in various parts of the profile in alternation with hard, brown and olive, lime-spotted clay. Silica, which may have precipitated from solution, possibly acts as one of the cementing agents of the hardpan because calcium carbonate is not always present.

Riggs soils are more or less alkaline, but the definite morphology often associated with alkali soils has not developed because of the fine texture, probable recent deposition of the stratified material, and the high content of neutral salts.

Kelton soils and Dune sand (partially stabilized) have formed from unstable shifting sands; therefore, definite horizons of soil development are largely absent. The Kelton soils are reddish brown and usually noncalcareous throughout, but traces of lime occur in the

deeper subsoil in places. In the barren, comparatively firm areas between dunes, a pinkish-gray crust may occur at the surface or at successive intervals in the profile. Dune sand (partially stabilized) is pale brown, loose, and moderately to strongly calcareous throughout.

LABORATORY DETERMINATIONS

Table 6 gives physical and chemical data relating to soil samples taken in the Sulphur Spring Valley area.[11]

[11] Analyses by H. V. Smith, associate agricultural chemist, University of Arizona.

TABLE 6.—*Analyses of soil samples of Sulphur Spring Valley area, Ariz.*[1]

Soil and depth (in inches)	Sand	Silt	Clay	Moisture equivalent	pH	Total soluble salts	Organic carbon	Calcium carbonate	Phosphorus	Potassium
	Percent	*Percent*	*Percent*	*Percent*		*ppm*	*Percent*	*Percent*	*ppm* [2]	*ppm* [2]
Briscoe sandy loam, nearly level:										
0–12	77. 1	19. 3	3. 6	14. 6	8. 1	528	0. 39	4. 22	0. 5	10
12–45	69. 1	20. 3	10. 6	16. 6	8. 2	915	. 28	6. 97	. 6	21
45–65	93. 1			5. 4	8. 0	640	. 09	4. 68	. 1	8
65–72	51. 1	41. 3	7. 6	23. 7	8. 0	1, 005	. 27	6. 81	. 8	15
Cogswell sandy loam:										
0–2	64. 7	22. 3	13. 0	17. 4	8. 5	570	. 80	. 41	3. 6	53
2–12	58. 7	23. 3	18. 0	19. 5	8. 5	545	. 72	2. 07	1. 1	54
12–26	59. 6	19. 4	21. 0	21. 7	8. 9	2, 375	. 36	5. 49	. 8	31
26+					8. 7		. 31	22. 61	2. 4	11
Continental sandy clay loam:										
0–4	63. 7	25. 3	11. 0	10. 2	8. 0	170	. 33	. 00	3. 5	22
4–12	47. 7	22. 4	29. 9	21. 4	7. 6	665	. 49	. 00	. 9	54
12–20	41. 7	40. 6	17. 7	24. 6	7. 9	1, 720	. 46	. 13	. 7	84
20–28	47. 7	14. 0	38. 0	25. 2	8. 2	1, 270	. 36	2. 08	. 8	72
28–40	61. 7	14. 0	24. 3	19. 1	8. 2	1, 090	. 27	4. 38	1. 5	74
40+	71. 7	16. 1	12. 2	14. 7	8. 1	1, 415	. 74	2. 76	1. 4	34
Courtland loamy coarse sand:										
0–10	84. 6	10. 0	5. 4	6. 4	7. 4	325	. 18	1. 66	3. 6	11
10–22	84. 6	10. 0	5. 4	34. 1	7. 9	234	. 20	. 48	2. 3	7
22–48	48. 2	18. 6	33. 2	24. 0	7. 7	665	. 33	. 38	. 6	9
48–72	79. 2	10. 4	10. 4	11. 6	8. 2	390	. 12	3. 24	. 7	14
Cowan loamy coarse sand:										
0–12	83. 3	9. 0	7. 7	6. 8	7. 9	370	. 15	. 04	1. 2	12
12–30	78. 3	12. 9	8. 8	8. 9	8. 2	330	. 19	. 00	1. 5	18
30–60	78. 3	13. 4	8. 3	9. 3	8. 5	415	. 08	. 44	1. 4	27
60–72				6. 8	8. 5	490	. 06	. 63	2. 8	27

Duncan loam:										
0–4	50. 6	32. 0	17. 4	16. 8	7. 4	425	. 29	. 84	6. 5	10
4–14	38. 6	26. 0	35. 4	25. 6	8.	1, 625	. 34	3. 84	1. 7	10
14–24 [3]										
24+	33. 6	32. 0	34. 4	8. 1	10. 0	3, 565	. 15	22. 94	2. 7	11
Elfrida sandy clay loam:										
0–2	66. 6	22. 0	11. 4	14. 5	7. 3	295	. 46	. 08	5. 4	36
2–12	55. 6	31. 0	13. 4	18. 2	7. 7	568	. 51	. 13	2. 5	49
12–36	67. 6	5. 0	27. 4	23. 9	8. 4	698	. 35	15. 54	. 9	29
36–72	62. 6	22. 0	15. 4	22. 2	8. 6	610	. 17	3. 20	1. 8	21
Forrest sandy clay loam:										
0–12	57. 0	16. 0	27. 0	15. 7	7. 9	655	. 40	1. 31	. 7	11
12–24	36. 0	23. 0	41. 0	20. 8	7. 9	570	. 35	1. 11	. 7	6
24–60	49. 0	28. 0	23. 0	16. 7	8. 0	560	. 21	9. 16	. 6	9
60–72				21. 7	8. 0	1, 460	. 18	13. 40	. 2	5
Frye sandy loam:										
0–2½	88. 8	17. 0	4. 2	6. 1	7. 4	198	. 23	. 37	. 9	12
2½–15	79. 8	13. 0	7. 2	9. 1	7. 8	215	. 20	. 08	. 5	15
15–22	71. 8	13. 0	15. 2	15. 1	7. 6	398	. 22	. 07	. 4	14
22+	86. 8			16. 3	8. 3	422	. 21	12. 50	. 8	20
Gothard sandy clay loam:										
0–2	67. 8	23. 0	9. 2	12. 1	8. 7	565	. 19	. 28	10. 5	8
2–10	41. 8	23. 0	35. 2	27. 7	10. 3	10, 385	. 26	3. 03	7. 9	7
10–45	25. 8	44. 0	30. 2	34. 6	10. 1	13, 165	. 22	3. 25	3. 4	11
45–57	63. 8	18. 0	18. 2	36. 6	8. 7	1, 485	. 14	1. 94	. 6	5
57–72	69. 8	11. 0	12. 2	23. 9	8. 6	1, 790	. 12	. 39	2. 6	3
Hooker clay loam:										
0–1½					6. 4	343	. 42	. 96	3. 2	26
1½–12	54. 2	26. 2	19. 6	17. 2	7. 7	392	. 39	. 24	1. 6	8
12–28	36. 2	42. 2	21. 6	23. 0	7. 7	392	. 48	. 05	1. 0	7
28–60	30. 8	47. 6	21. 6	25. 3	7. 7	590	. 49	. 20	1. 7	8
60–72	54. 2	30. 2	15. 6	15. 9	7. 9	522	. 27	. 10	2. 7	7
Karro sandy loam:										
0–6	69. 1	18. 3	12. 6	25. 1	8. 3	660	. 79	20. 28	4. 0	67
6–16	75. 1	13. 3	11. 6	26. 4	8. 3	640	. 87	18. 96	2. 0	85
16+	73. 1	7. 3	19. 6	23. 7	8. 1	2, 470	. 30	28. 52	. 5	103

See footnotes at end of table.

TABLE 6.—*Analyses of soil samples of Sulphur Spring Valley area, Ariz.*[1]—Continued

Soil and depth (in inches)	Sand	Silt	Clay	Moisture equivalent	pH	Total soluble salts	Organic carbon	Calcium carbonate	Phosphorus	Potassium
Kelton loamy sand:	*Percent*	*Percent*	*Percent*	*Percent*		*ppm*	*Percent*	*Percent*	*ppm* [2]	*ppm* [2]
0–9	89. 1	3. 3	7. 6	4. 0	7. 1	212	0. 17	1. 04	0. 6	10
9–24	91. 1	1. 3	7. 6	4. 6	6. 9	190	. 16	. 21	. 7	4
24–60	91. 1	1. 3	7. 6	5. 0	7. 3	170	. 10	. 03	. 7	6
60–72	90. 1	2. 3	7. 6	6. 7	7. 7	217	. 07	. 06	. 8	8
McAllister sandy clay loam: [4]										
0–6	69. 1	22. 3	8. 6	18. 4	7. 9	331	. 43	. 75	. 1	10
6–16	73. 1	9. 3	17. 6	23. 1	8. 2	532	. 41	4. 16	. 5	27
16–24	59. 1	23. 3	17. 6	23. 0	8. 2	632	. 46	14. 58	. 6	38
24+	51. 6	28. 0	20. 4	--------	8. 2	702	. 31	17. 06	2. 4	25
McNeal sandy loam:										
0–10	66. 6	16. 0	17. 4	17. 7	7. 3	355	. 38	1. 38	1. 0	19
10–18	44. 6	16. 0	39. 4	28. 6	7. 9	1, 575	. 45	6. 87	. 3	26
18–45	74. 6	6. 0	19. 4	16. 2	8. 3	458	. 13	13. 84	. 6	27
45–72	94. 6	3. 0	2. 4	5. 2	9. 1	235	. 06	5. 43	2. 2	20
Mimbres clay loam:										
0–1½	40. 7	38. 0	21. 3	25. 0	6. 6	425	. 99	. 06	9. 0	30
1½–16	31. 7	39. 3	29. 0	26. 2	7. 8	1, 290	. 89	. 67	. 9	38
16–36	17. 3	48. 0	34. 7	30. 0	8. 2	1, 522	. 18	1. 91	1. 8	26
36–48	51. 8	40. 0	8. 2	22. 4	8. 0	3, 220	. 41	3. 74	1. 4	11
48+	49. 8	--------	--------	22. 0	8. 0	3, 480	. 30	4. 98	. 9	9
Riggs clay:										
0–8	51. 1	34. 7	14. 2	24. 0	8. 3	610	. 47	2. 48	1. 0	19
8–36	28. 8	17. 3	53. 9	40. 9	8. 6	9, 620	. 66	9. 06	1. 9	10
36–45	23. 8	72. 7	3. 5	42. 2	8. 4	16, 500	. 49	14. 80	. 8	11
45–72	37. 8	22. 2	40. 0	63. 7	8. 0	3, 745	. 23	. 50	8. 4	1

Rucker sandy loam:										
0–12	78. 6	14. 0	7. 4	10. 6	7. 4	330	. 31	. 08	. 8	22
12–24	81. 6	14. 0	4. 4	11. 7	8. 0	332	. 21	. 11	2. 0	10
24–48	74. 6	12. 0	13. 4	21. 6	8. 0	780	. 37	. 25	1. 3	8
48–72	30. 6	50. 0	19. 4	28. 8	7. 9	840	. 49	. 07	3. 2	7
Sonoita sandy loam:										
0–4	73. 7	15. 3	11. 0	8. 2	6. 1	155	. 28	. 00	-------	22
4–14	71. 7	13. 0	15. 3	9. 8	7. 4	175	. 26	. 00	2. 6	26
14–26	70. 7	8. 3	21. 0	16. 2	7. 6	260	. 48	. 00	. 6	14
26–40	73. 7	11. 3	15. 0	13. 1	7. 8	390	. 44	. 00	1. 0	19
40+	89. 7	5. 3	5. 0	4. 6	8. 1	275	. 10	. 10	2. 3	12
Stewart loam:										
0–3	50. 6	32. 6	16. 8	25. 2	8. 4	2, 665	. 54	. 38	5. 6	18
3–14	35. 8	38. 0	26. 2	31. 7	10. 2	6, 025	..36	6. 36	8. 1	10
14–16	85. 6	9. 0	5. 4	17. 2	10. 7	2, 275	. 14	2. 20	4. 0	7
16–40	57. 8	27. 7	14. 4	29. 9	10. 3	2, 900	. 28	7. 06	2. 3	2
40–48	93. 8	4. 7	1. 5	6. 5	10. 3	975	. 10	1. 68	1. 5	2
48+	37. 8	44. 0	18. 2	28. 2	9. 8	1, 795	. 10	. 56	1. 8	1

[1] Mechanical analyses by hydrometer (Bouyoucos) method.
[2] CO_2 soluble phosphorus and potassium.
[3] Not sampled.
[4] Subsoil is coarser in texture than dominantly occurs.

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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL MAP
SULPHUR SPRINGS VALLEY AREA - ARIZONA
SHEET NO. 1

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION

R. 23 E. | R. 24 E. | R. 25 E. | R. 26 E.

109°55' | 109°50' | 109°45'

T. 12 S. | T. 13 S. | T. 14 S. | T. 15 S. | T. 16 S.

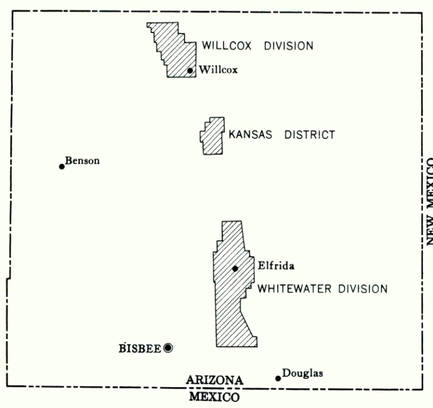
32°20' | 32°15' | 32°05' | 32°00'

KANSAS DISTRICT

WILLCOX DIVISION

Dickinson Ranch | J. H. Well | HOOKERS | DRAW | Stewart School | Fischer Ranch | 4 Willcox Municipal Airport | WILLCOX

DIAGRAM
Showing location of Area in Cochise County



LEGEND

Briscoe gravelly sandy loam, nearly level — Ba	Briscoe sandy loam, nearly level — Bf	Continental sandy clay loam, eroded — Ce	Duncan loam — Da	Elfrida silty clay loam — Ed	Forrest sandy clay loam, hummocky — Fe	Hooker clay loam — Ha	Karro loamy sand, hummocky — Kc	McAllister loamy sand — Ma	Mimbres clay loam — Mf	Rucker sandy loam — Rd	
Briscoe gravelly sandy loam, very gently sloping, eroded — Bb	Cogswell sandy clay loam — Ca	Continental sandy loam — Cf	Dune sand (partially stabilized) — Db	Forrest clay — Fa	Frye sandy clay loam — Ff	Hooker clay loam, eroded — Hb	Karro sandy loam — Kd	McAllister loamy sand, hummocky — Mb	Mimbres loam — Mg	Sonoita sandy loam — Sa	
Briscoe loam — Bc	Cogswell sandy loam — Cb	Courtland loamy coarse sand — Cg	Elfrida clay loam — Ea	Forrest clay loam — Fb	Frye sandy loam — Fg	Hooker sandy loam — Hc	Karro sandy loam, hummocky — Ke	McAllister sandy clay loam — Mc	Riggs clay — Ra	Stewart loam — Sb	
Briscoe loam, deep, over Forrest soil material — Bd	Continental gravelly sandy loam — Cc	Courtland loamy coarse sand, eroded — Ch	Elfrida-Gothard loams — Eb	Forrest gravelly sandy loam — Fc	Gothard sandy clay loam — Ga	Karro loam — Ka	Kelton loamy sand — Kf	McAllister sandy loam — Md	Riggs clay loam — Rb	Stewart sandy loam — Sc	
Briscoe sandy loam, hummocky — Be	Continental sandy clay loam — Cd	Cowan loamy coarse sand — Ck	Elfrida sandy clay loam — Ec	Forrest sandy clay loam — Fd	Gothard sandy loam — Gb	Karro loamy sand — Kb	Kelton loamy sand, hummocky — Kg	McNeal sandy loam — Me	Rucker gravelly sandy loam — Rc	Tubac sandy loam — Ta	

See Sheet No. 2 for color grouping, saline and alkali legend.

CONVENTIONAL SIGNS

CULTURE
(Printed in black)

- City or Village, Roads, Buildings, Wharves, Jetties, Breakwater, Levee, Lighthouse, Fort
- Secondary roads, Trails
- Railroads
- Bridges, Ferry
- Railroad crossings
- Ford, Dam, Sawmill, Windmill
- Boundary lines
- School, Church, Creamery, Cemeteries
- Boundary lines
- Triangulation station, Boundary monument, Oil or Gas wells
- U. S. Township and Section lines, Recovered corners
- Forest fire station, Airway beacon, Oil or Gas tanks
- Transmission line, Oil or Gas pipe line
- Mine or Quarry, Gravel pit, Rock outcrop, Made land
- Soil boundaries; Stony, Gravelly, and Cherty areas

RELIEF
(Printed in brown or black)

- Contours, Depression contours
- Prominent hills or Mountain peaks
- Sand, Wash, Sand dunes
- Bluff, Escarpment, Mine dumps

DRAINAGE
(Printed in blue)

- Streams, Springs, Wells, Flowing wells
- Lakes, Ponds, Intermittent lakes
- Gully, Intermittent streams
- Water pipe lines, Canals, Ditches, Flumes
- Swamp, Salt marsh
- Submerged marsh, Tidal flats

The above signs are in current use on the soil maps. Variations from this usage appear in some maps of earlier dates.

J. Kenneth Ableiter, Chief Soil Correlator.
W. H. Allaway, Chief Analyst, Soil Uses and Productivity.
R. C. Roberts Principal Soil Correlator, Far Western States.
Correlation and inspection by A. T. Strahorn, Senior Soil Scientist.
Soils surveyed 1938-40 by E. N. Poulson, in charge, A. T. Sweet, and J. W. Bailey, U. S. Department of Agriculture.

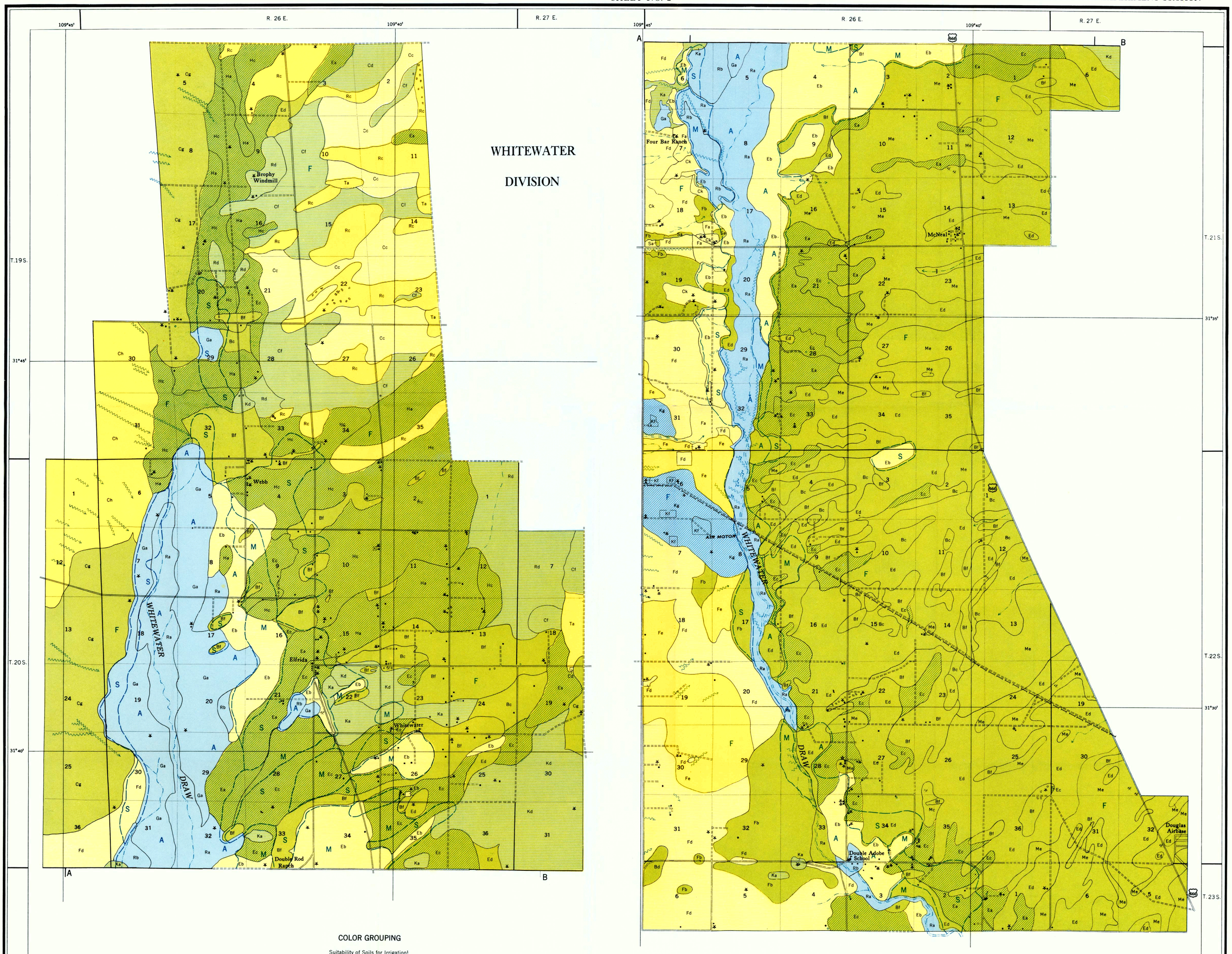
Scale 1:48,000
1 0 1 2 3 Miles
5000 0 5000 10000 Feet

Map compiled by the Cartographic Division, Soil Conservation Service, from plane table traverse, USGS topographic quadrangles, and GLO plats.
Polyconic projection.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL MAP
SULPHUR SPRINGS VALLEY AREA - ARIZONA
SHEET NO. 2

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION



COLOR GROUPING

Suitability of Soils for Irrigation[1]
(Provided water is available)

SOILS EXCELLENT FOR IRRIGATION

Elfrida clay loam
Elfrida sandy clay loam
Hooker clay loam
Hooker sandy loam
Mimbres clay loam
Mimbres loam

SOILS WELL SUITED TO IRRIGATION

Briscoe loam
Briscoe sandy loam, nearly level
Briscoe loam, deep, over Forrest soil material
Cogswell sandy loam
Cogswell sandy clay loam
Courtland loamy coarse sand
Elfrida silty clay loam
Forrest clay loam
Frye sandy loam
Frye sandy clay loam
McAllister loamy sand
McAllister sandy clay loam
McAllister sandy loam
McNeal sandy loam
Sonoita sandy loam

SOILS MODERATELY WELL SUITED TO IRRIGATION

Briscoe gravelly sandy loam, nearly level
Continental sandy clay loam
Continental sandy loam
Karro loam } Except for areas affected by toxic
Karro sandy loam } salts and alkali. See footnote.
Rucker sandy loam

SOILS INTERMEDIATE IN SUITABILITY TO IRRIGATION

Briscoe sandy loam, hummocky
Continental gravelly sandy loam
Cowan loamy coarse sand
Elfrida-Gothard loams
Forrest clay
Forrest gravelly sandy loam
Forrest sandy clay loam

SOILS POORLY SUITED TO IRRIGATION

Briscoe gravelly sandy loam, very gently sloping, eroded
Continental sandy clay loam, eroded
Courtland loamy coarse sand, eroded
Forrest sandy clay loam, hummocky
Hooker clay loam, eroded
Karro loamy sand
Karro loamy sand, hummocky
Karro sandy loam, hummocky
McAllister loamy sand, hummocky
Rucker gravelly sandy loam
Tubac sandy loam

SOILS SUITED TO IRRIGATION ONLY AFTER COMPLEX RECLAMATION PRACTICES

Duncan loam
Gothard sandy clay loam
Gothard sandy loam
Riggs clay
Riggs clay loam
(In addition, areas of other soils indicated on the map with broken outline and letters "M" or "A" in blue. See footnote.)

SOILS NOT SUITED TO IRRIGATION

Dune sand (partially stabilized)
Kelton loamy sand
Kelton loamy sand, hummocky
Stewart loam
Stewart sandy loam

[1]The soils of all areas outlined on the map with broken blue line and marked with blue letters "M" or "A", regardless of other map coloring, are affected more or less with toxic salts and/or alkali, and are made suitable for irrigation only with the aid of complex reclamation practices.

SALINE AND ALKALI SOILS

(F) *Areas essentially free of harmful concentrations of soluble salts and/or alkali*
(S) *Areas slightly affected by soluble salts and/or alkali*
(M) *Areas moderately affected by soluble salts and/or alkali*
(A) *Areas strongly affected by soluble salts and/or alkali*

NOTE: The significance of these symbols is more fully explained and defined in the section on Salts, Alkali, and Drainage, in the report.

See sheet No. 1 for alphabetical legend, conventional signs, and diagram showing location of areas surveyed.

J. Kenneth Ableiter, Chief Soil Correlator.
W. H. Allaway, Chief Analyst, Soil Uses and Productivity.
R. C. Roberts Principal Soil Correlator, Far Western States.
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Scale 1:48,000
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Polyconic projection.